RESEARCH ARTICLE

Re-exposure in cone beam CT of the dentomaxillofacial region: a retrospective study

¹Yasamin Habibi, ²Edriss Habibi and ¹Bilal Al-Nawas

¹Department of Oral and Maxillofacial Surgery, Plastic Surgery, University Medical Center of the Johannes Gutenberg-University Mainz, Mainz, Germany; ²Department of Prosthodontics, University of Heidelberg, Dental School, Heidelberg, Germany

Objectives: Cone beam CT (CBCT) often uses a smaller field of view compared to conventional CT scans. This might lead to a wrong field of view with the need for secondary exposure (“retakes”). The purpose of this retrospective study was to assess the frequency of re-exposures in CBCT and to identify whether the parameters age, gender, and field of view have an influence on the re-exposure of the patient. Additionally, the causes of re-exposures were determined and categorized.

Methods: In a retrospective cohort study CBCT images of 4986 patients from the patient database from the Department of Oral Radiology, University Medical Center of the Johannes Gutenberg University, Mainz, Germany were included and the rate of re-exposures was counted. Patients were stratified into those who received a scan with the small field-of-view CBCT or the large field-of-view CBCT. The effect of patient-related parameters as age and gender was implicated. As a further device-specific parameter, the statistical analysis included whether the selection of the field of view due to the device type had a significant influence on the occurrence of re-exposures. Furthermore, the rescans were analyzed with regard to their causes.

Results: In total, CBCT images of 82 (1.6%) patients had to be repeated. Looking at the two different devices, in 42 (1.3%) patients that received a scan with the large field-of-view CBCT and in 40 (2.3%) patients that received a scan with the small field-of-view CBCT respectively needed a retake. There was no statistically significant correlation between age and gender to retakes. For the small field-of-view-size significantly more retakes were observed than for the large one. With 46% motion artifacts were the most frequent causes for a re-exposure of the patient.

Conclusions: Gender and age did not have an impact on the occurrence of re-exposures. Patients who received a scan with the small field-of-view CBCT were significantly more often rescanned than those with the large field-of-view CBCT.

Dentomaxillofacial Radiology (2019) **48**, 20180184. doi: [10.1259/dmfr.20180184](https://doi.org/10.1259/dmfr.20180184)

Cite this article as: Habibi Y, Habibi E, Al-Nawas B. Re-exposure in cone beam CT of the dentomaxillofacial region: a retrospective study. *Dentomaxillofac Radiol* 2019; **48**: 20180184.

Keywords: CBCT; large field-of-view CBCT; small field-of-view CBCT

Introduction

Radiological imaging is an essential complement for the clinical evaluation and treatment planning in dentistry.¹ Currently dental radiology has a broad range of imaging methods. Panoramic radiography is one of the most common imaging techniques used in dental

practice.^{2,3} Since two-dimensional radiographs can be obtained easily.⁴ However, it delivers limited information concerning complex anatomical structures due to inherent limitations such as superimposition, artifacts, and distortion.¹ As a new three-dimensional (3D) imaging procedure cone beam CT (CBCT) was first introduced in 1998 by Mozzo and Procacci.⁵ In complex instances 3D imaging can be a relevant adjunctive tool

Correspondence to: Dr Yasamin Habibi, E-mail: jashabibi@googlemail.com

Received 07 May 2018; revised 04 December 2018; accepted 07 December 2018

Table 1 Number of re-exposures

			Large field-of-view CBCT	Small field-of- view CBCT	Total
Re-exposure	No	Number	3210	1693	4903
		%	98.7%	97.7%	98.4%
	Yes	Number	42	40	82
		%	1.3%	2.3%	1.6%
Total			3252	1733	4985
			100.0%	100.0%	100.0%

CBCT, cone beam CT.

to conventional radiological imaging. Recently, CBCT has become an increasingly important and indispensable diagnostic tool in oral and maxillofacial radiology because it delivers images with relatively high resolution of bone structures.^{6–8} CBCT allocates a plurality of advantages but holds also some drawbacks.

The wide acceptance of this imaging technique is achieved by its cost-effectiveness and since the exposure is conducted in CBCT-devices that look relatively similar to panoramic units.^{1,9,10} Furthermore CBCT has got an extended field of application. It is mainly used for the assessment of osseous structures. The use in oral and maxillofacial surgery implies the accurate analysis of pathologies and the assessment of impacted teeth.^{11–13} In orthognathic surgery it delivers detailed information about dentofacial deformities in order to enable an accurate surgical planning and to optimize treatment outcomes.^{14–16} In implant dentistry CBCT scans are experiencing an increasing demand. The evaluation of bone quantity and quality can be performed

adequately. It delivers accurate measurements for the pre- and post-operative assessment.^{17,18}

Although CBCT has become a crucial diagnostic imaging method in dentistry and the fact that it in general provides compared to conventional CT a remarkable dose reduction,^{19,20} all clinicians should be aware of the ALARA principle which demands that radiation doses to patients and personnel be kept As Low As Reasonably Achievable.²¹

Currently CBCT technology has certain limitations that interfere with image accuracy. Especially artifacts in images as patient-related artifacts, scanner-related artifacts also known as technical problems may lead to a substantial decrease in image quality.^{1,22–24}

Considering this in some cases a rescanning of the patient may be needed. The re-examination leads to a re-exposure for the patient. In literature there is little information about the prevalence of retakes and their causes based on CBCT systems. In the case of patient-related artifacts, patient movement detection and movement artifacts have a great impact on image quality.¹ Image reconstruction requires a rigid positioning but it is not possible to completely immobilize the patient during the scan due to physiological processes as breathing and swallowing. The decrease of image quality is expressed in double contours and overall lack of sharpness.^{25,26} The technical problems of CBCT implicate for example scanner-related artifacts and poor calibration.¹

Therefore, the objective of this retrospective study was to identify the frequency of retakes in cone bCBCTin a University Medical Center environment. Additionally the reasons for re-exposure should be analyzed and categorized.

Methods and materials

Study setting

In this retrospective study, 4986 patients were included who received a CBCT scan in the Department of Oral Radiology of the University Medical Centre, Mainz, Germany between the time period from 2006 to 2014. Data were obtained from the database of the 3D examination (KaVo Dental GmbH, Biberach, Germany) and from the 3D Accuitomo 80 (J. Morita Corp. Kyoto, Japan). All patient- and image-data

Figure 1 Movement artifacts in CBCT.

Table 2 Cause for re-exposure for the large field-of-view CBCT

		<i>Motion artifact</i>	<i>Technical failure</i>	<i>II</i>	<i>Others</i>	<i>Total</i>
Total	3252	18 43%	3 7%	14 33%	7 17%	42

CBCT, cone beam CT.

were documented according to a structured process. Descriptive statistical methods were used to evaluate data.

Besides epidemiological information such as gender and age, the patient-related clinical data files included medical indication and clinical implication. Image-related data included the parameters acquisition time, voxel size, and dosage.

Additionally, the corresponding CBCT of every scan was analyzed and individually documented. If necessary the electronic patient information system was used to complete data. All CBCT images were classified according to the device type with the corresponding viewer software. The patient population of 4986 patients was categorized. The number of CBCT scans made individually for each patient was taken into account. The CBCT scans of patients with multiple images were investigated to determine whether a re-exposure occurred (yes *vs* no). Furthermore the causes were determined that led to a re-exposure. In this respect four categories were defined: motion artifacts, technical errors, incompleteness of the image, and the category others which implicates different combinations of the three types and operator-related aspects.

It was investigated whether there is a correlation between re-exposures and specific parameters as gender, age or if the frequency of a further re-exposition of the patient is affected by the size of the field of view of the device type. Pearson's chi-square test was used to examine the influence of gender and field of view of the individual device types. T-test was used to assess the impact of age on re-exposures and whether patients of specific age cohorts were more likely to suffer from re-exposure.

In this analysis *p*-values < 0.05 were termed as statistically significant.

In certain analysis due to inaccurate or inadequate data, patients were excluded on the basis of individual parameters. The statistical analysis was conducted using SPSS IBM Statistics v. 23.0 (SPSS Inc., Chicago, IL).

Table 3 Cause for re-exposure for the small field-of-view CBCT

		<i>Motion artifact</i>	<i>Technical failure</i>	<i>II</i>	<i>Others</i>	<i>Total</i>
Total	1733	20 50%	4 10%	14 35%	2 5%	40

CBCT, cone beam CT.

Results

A total of 4986 patients were evaluated. In this study 2584 (51.9%) patients were males and 2398 (48.1%) were females. The total group showed an average age of 45.1 years with a standard deviation of 20.59 years. In 82 (1.6%) patients of 4985 a retake was indicated. The two device types, the small field-of-view CBCT, and the large field-of-view CBCT were also evaluated separately. Of the 3252 patients that obtained an image with the large field-of-view CBCT 1.3% required a rescan. Accordingly from the 1733 that received an imaging with the small field-of-view CBCT 2.3% needed a retake (Table 1).

Regarding the causes, as the most frequent reason for a rescanning motion artifacts with 38 (46%) were implicated. 28 (34%) patients received a retake due to incompleteness of the scan and technical errors and defects were represented in 7 (9%) patients. 9 (11%) patients were categorized in Others. A separate analysis in regard to the two device types revealed for the large field-of-view CBCT that 18 (43%) patients obtained a rescanning because of motion artifacts. 14 (33%) patients can be assigned to the category incompleteness of the scan and 3 (7%) patients needed a rescan due to technical complications. The category Others was represented with 7 (17%) patients (Table 2). Additionally, results for the small field-of-view CBCT revealed for the following categories: 20 (50%) patients for motion artifacts, 14 (33%) patients for incompleteness of the scan, 4 (10%) patients due to technical problems, and others with 2 (5%) patients (Table 3).

Pearson's chi-square test showed that there is a statistical significant difference regarding the occurrence of retakes between the large and small field-of-view CBCT (*p* = 0.007). We observed no statistical correlation between gender and the occurrence of retakes (*p* = 0.320). T-test was used to verify if there is a correlation between the parameter age and retake. An influence of age on the occurrence of retakes could not be confirmed due to the results in this study (*p* = 0.238).

Discussion

The frequency of retakes in CBCT and their causes were examined in this retrospective study. Radiation safety and protection are an essential component in radiology. The ALARA principle is a fundamental practice mandate.^{21,27} CBCT as a relatively new imaging technique in general has a lower radiation dose compared to other conventional imaging methods like CT.^{19,20} This imaging technique is not only associated with advantages but there are also certain limitations. In particular the presence of artifacts can lead to a degradation of the image qualities and can render them unusable for further diagnosis and treatment planning.^{28,29} In such cases a rescan might be required.

The results of this study showed that in total 1.6% of the patients in our sample required a retake. A differentiation between the two device types revealed that 2.3% patients of the small field-of-view CBCT and 1.3% patients of the large field-of-view CBCT received a retake. In a previous study from Donaldson²⁶ 0.5% of the images needed a rescan for diagnostic reasons.³⁰ A study by Spin-Neto reported that 6.4% of the examinations needed to be redone.³¹

The European Commission Directorate for Energy currently states that a maximum of 5% of CBCT images might be in need of a retake.³²

The evaluation in our retrospective study concerning the causes for retakes led to a division into four different groups. The most common reason for a rescan was with 46% movement artifacts (Figure 1). Technical problems were mentioned with 9%, incompleteness of the image with 34% and others which imply different combinations of the three categories and operator-related aspects were represented with 11%. According to the literature patient-related artifacts such as motion artifacts result in a geometric misregistration of the data which represents itself in the reconstructed image as overall unsharpness and sometimes double contours. This may cause a significant decrease of image quality.^{1,33} A systematic review by Spin-Neto²⁵ reports that in 20% of cases a movement by patients during CBCT examination was registered and that studies concerning image artifact recognition stated a prevalence of 41.5% patient movement.²⁵ Numerous reasons for movement artifacts are discussed. In this context, the age range is frequently defined as a relevant factor for movement artifacts.³¹ In particular many studies reported that images of older and younger patients more frequently show movement artifacts.³⁴ In this study technical problems were closely linked to aspects like system errors in general, poor calibration or difficulties in scanner detection. In our study 34% of the re-exposures were allocated to incompleteness of the image. This implicated mainly the aspect that the field of view was not

adjusted adequately, so that the region of interest was not completely captured.

Among other things the present study analyzed whether age, gender or the device type selected had a decisive influence on the occurrence of retakes. Our data observed no statistical correlation of the factors as gender and age. We only observed an influence of the device type and thus field of view, with a higher number of retakes for the smaller field-of-view. This contradicts the findings of Spin-Neto³¹ who observed that the use of a large field-of-view was more frequently associated with a re-exposure. In this context, it should be taken into account that Spin-Neto has considered only one field-of-view size in his work while multiple small field-of-view sizes were included in this study.

Notwithstanding the method of radiological examination, it is important to keep the patient's radiation exposure as low as possible according to the ALARA principle. Thus retakes should be avoided or at least their number should be minimized. The knowledge and analysis of factors that lead to artifacts and impairment of image quality are a central topic when working with CBCT devices.

Conclusion

The limitations of this retrospective study include that only two types of CBCT machines were included and that in particular patients acquired at a University Medical Center may exhibit more severe diseases and illness than in regular offices with an orofacial focus. Furthermore it must be taken into account that most of the CBCT images received a scout image in advance to avoid a re-exposure.

Today CBCT is an indispensable component in maxillofacial imaging. Central issues like artifacts as well as other limitations that lead to a retake need to be considered. Our study indicated that retakes seem to be more common for small fields-of-view compared to large fields-of-view.

References

1. Scarfe WC, Farman AG. What is cone-beam CT and how does it work? *Dent Clin North Am* 2008; **52**: 707–30. doi: <https://doi.org/10.1016/j.cden.2008.05.005>
2. Dannewitz B, Hassfeld S, Eickholz P, Mühling J. Effect of dose reduction in digital dental panoramic radiography on image quality. *Dentomaxillofac Radiol* 2002; **31**: 50–5. doi: <https://doi.org/10.1038/sj.dmfr.4600651>
3. Boeddinghaus R, Whyte A. Current concepts in maxillofacial imaging. *Eur J Radiol* 2008; **66**: 396–418. doi: <https://doi.org/10.1016/j.ejrad.2007.11.019>
4. Dau M, Marciak P, Al-Nawas B, Staedt H, Alshiri A, Frerich B, et al. Evaluation of symptomatic maxillary sinus pathologies using panoramic radiography and cone beam computed tomography-influence of professional training. *Int J Implant Dent* 2017; **3**: 13. doi: <https://doi.org/10.1186/s40729-017-0075-5>
5. Mozzo P, Procacci C, Tacconi A, Tinazzi Martini P, Bergamo Andreis IA, Martini PT, Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. *European Radiology* 1998; **8**: 1558–64. doi: <https://doi.org/10.1007/s003300050586>
6. Pauwels R, Jacobs R, Singer SR, Mupparapu M. CBCT-based bone quality assessment: are Hounsfield units applicable? *Dentomaxillofac Radiology* 2015; **44**: 20140238. doi: <https://doi.org/10.1259/dmfr.20140238>
7. Al-Okshi A, Lindh C, Salé H, Gunnarsson M, Rohlin M. Effective dose of cone beam CT (CBCT) of the facial skeleton: a systematic review. *Bri J Rad* 2015; **88**: 20140658. doi: <https://doi.org/10.1259/bjr.20140658>
8. Stutzki M, Jahns E, Mandapathil MM, Diogo I, Werner JA, Güldner C. Indications of cone beam CT in head and neck imaging.

- Acta Otolaryngol* 2015; **135**: 1337–43. doi: <https://doi.org/10.3109/00016489.2015.1076172>
9. Nemtoi A, Czink C, Haba D, Gahleitner A. Cone beam CT: a current overview of devices. *Dentomaxillofac Radiol* 2013; **42**: 20120443. doi: <https://doi.org/10.1259/dmfr.20120443>
10. Suomalainen A, Pakbaznejad Esmaili E, Robinson S. Dentomaxillofacial imaging with panoramic views and cone beam CT. *Insights Imaging* 2015; **6**: 1–16. doi: <https://doi.org/10.1007/s13244-014-0379-4>
11. Wriedt S, Jaklin J, Al-Nawas B, Wehrbein H. Impacted upper canines: examination and treatment proposal based on 3D versus 2D diagnosis. *Journal of Orofacial Orthopedics / Fortschritte der Kieferorthopädie* 2012; **73**: 28–40. doi: <https://doi.org/10.1007/s00056-011-0058-8>
12. Dau M, Marciak P, Al-Nawas B, Staedt H, Alshiri A, Frerich B, et al. Evaluation of symptomatic maxillary sinus pathologies using panoramic radiography and cone beam computed tomography-influence of professional training. *Int J Implant Dent* 2017; **3**: 13. doi: <https://doi.org/10.1186/s40729-017-0075-5>
13. Jeremias F, Fragelli CM, Mastrantonio SD, Dos Santos-Pinto L, Dos Santos-Pinto A, Pansani CA. Cone-beam computed tomography as a surgical guide to impacted anterior teeth. *Dent Res J* 2016; **13**: 85. doi: <https://doi.org/10.4103/1735-3327.174723>
14. Weissheimer A, Menezes LM, Koerich L, Pham J, Cevidanes LH. Fast three-dimensional superimposition of cone beam computed tomography for orthopaedics and orthognathic surgery evaluation. *Int J Oral Maxillofac Surg* 2015; **44**: 1188–96. doi: <https://doi.org/10.1016/j.ijom.2015.04.001>
15. Cevidanes LHS, Alhadidi A, Paniagua B, Styner M, Ludlow J, Mol A, et al. Three-dimensional quantification of mandibular asymmetry through cone-beam computerized tomography. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* 2011; **111**: 757–70. doi: <https://doi.org/10.1016/j.tripleo.2011.02.002>
16. Hwang HS, Hwang CH, Lee KH, Kang BC. Maxillofacial 3-dimensional image analysis for the diagnosis of facial asymmetry. *Am J Orthod Dentofacial Orthop* 2006; **130**: 779–85. doi: <https://doi.org/10.1016/j.ajodo.2005.02.021>
17. Neugebauer J, Ritter L, Mischkowski R, Zöller JE. Three-dimensional diagnostics, planning and implementation in implantology. *Int J Comput Dent* 2006; **9**: 307.
18. Bornstein MM, Scarfe WC, Vaughn VM, Jacobs R. Cone beam computed tomography in implant dentistry: a systematic review focusing on guidelines, indications, and radiation dose risks. *Int J Oral Maxillofac Implants* 2014; **29 Suppl**(Supplement): 55–77. doi: <https://doi.org/10.11607/jomi.2014suppl.g1.4>
19. Kyriakou Y, Kolditz D, Langner O, Krause J, Kalender W. Digital volume tomography (DVT) and multislice spiral CT (MSCT): an objective examination of dose and image quality. *Rofo* 2011; **183**: 144–53. doi: <https://doi.org/10.1055/s-0029-1245709>
20. Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3 CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G and i-CAT. *Dentomaxillofac Radiol* 2006; **35**: 219–26. doi: <https://doi.org/10.1259/dmfr/14340323>
21. Farman AG. ALARA still applies. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* 2005; **100**: 395–7. doi: <https://doi.org/10.1016/j.tripleo.2005.05.055>
22. Schulze R, Heil U, Gross D, Bruellmann DD, Dranischnikow E, Schwanecke U, et al. Artefacts in CBCT: a review. *Dentomaxillofac Radiol* 2011; **40**: 265–73. doi: <https://doi.org/10.1259/dmfr/30642039>
23. Draenert FG, Coppenrath E, Herzog P, Müller S, Mueller-Lisse UG. Beam hardening artefacts occur in dental implant scans with the NewTom cone beam CT but not with the dental 4-row multidetector CT. *Dentomaxillofac Radiol* 2007; **36**: 198–203. doi: <https://doi.org/10.1259/dmfr/32579161>
24. Pauwels R, Stamatakis H, Bosmans H, Bogaerts R, Jacobs R, Horner K, et al. Quantification of metal artifacts on cone beam computed tomography images. *Clin Oral Implants Res* 2013; **24 Suppl A100**: 94–9. doi: <https://doi.org/10.1111/j.1600-0501.2011.02382.x>
25. Spin-Neto R, Wenzel A. Patient movement and motion artefacts in cone beam computed tomography of the dentomaxillofacial region: a systematic literature review. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2016; **121**: 425–33. doi: <https://doi.org/10.1016/j.oooo.2015.11.019>
26. Donaldson K, O'Connor S, Heath N. Dental cone beam CT image quality possibly reduced by patient movement. *Dentomaxillofac Radiol* 2013; **42**: 91866873. doi: <https://doi.org/10.1259/dmfr/91866873>
27. Presbyterian C. “The ALARA concept in pediatric CT intelligent dose reduction.”. *Pediatr Radiol* 2002; **32**: 219–20.
28. Nagarajappa AK, Dwivedi N, Tiwari R. Artifacts: The downturn of CBCT image. *J Int Soc Prev Community Dent* 2015; **5**: 440. doi: <https://doi.org/10.4103/2231-0762.170523>
29. Makins SR. Artifacts interfering with interpretation of cone beam computed tomography images. *Dent Clin North Am* 2014; **58**: 485–95. doi: <https://doi.org/10.1016/j.cden.2014.04.007>
30. Donaldson K, O'Connor S, Heath N. Dental cone beam CT image quality possibly reduced by patient movement. *Dentomaxillofac Radiol* 2013; **42**: 91866873. doi: <https://doi.org/10.1259/dmfr/91866873>
31. Spin-Neto R, Matzen LH, Schropp L, Gotfredsen E, Wenzel A. Factors affecting patient movement and re-exposure in cone beam computed tomography examination. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2015; **119**: 572–8. doi: <https://doi.org/10.1016/j.oooo.2015.01.011>
32. Project S. *Radiation Protection n172: Cone Beam CT for Dental and Maxillofacial Radiology*. Luxembourg: European Commission Directorate-General for Energy; 2012.
33. Yıldizer Keriş E, Keriş EY. Effect of patient anxiety on image motion artefacts in CBCT. *BMC Oral Health* 2017; **17**: 73. doi: <https://doi.org/10.1186/s12903-017-0367-4>
34. Nardi C, Borri C, Regini F, Calistri L, Castellani A, Lorini C, et al. Metal and motion artifacts by cone beam computed tomography (CBCT) in dental and maxillofacial study. *Radiol Med* 2015; **120**: 618–26. doi: <https://doi.org/10.1007/s11547-015-0496-2>