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IMPACT OF FIELD OF VIEW ON CONE BEAM COMPUTED TOMOGRAPHY VOXEL DENSITY VALUE: A SYSTEMATIC REVIEW

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ABSTRACT

Objective: This systematic review was to criticize the impact of field of view on cone beam computed tomography voxel density value based on analysis of the literature reported the effect of field of view on cone beam computed tomography voxel density value directly or indirectly.

Methods: Searches were done on Medline, Embase libraries via PubMed search engine, and on Cochrane library via its engine. Mesh keywords were used to ensure detection of potential variation. Considering the following criteria. **Inclusion criteria:** Studies with clear specifications of the machine used, with clear exposure parameters (Kvp, mA, FOV size and voxel size), having a gold standard for comparison. Exclusion criteria, Studies with fixed FOV. Review articles. Case study

Results: Analysis of the search was done on two levels. The first was by titles and abstracts. The second, re-analysis of the accepted studies. Those included underwent data extraction, summarized in a table with headings: title, first author, journal, publication' year, machines' numbers, kind, and exposure parameters.

Conclusion: Several points was as an answer for our research question. The field of view is one of the most important factors influencing VDV of CBCT and image quality. Regarding the size of FOV. It is directly proportional to the amount of radiation the patient expose to, it should be small to maximize spatial resolution, large enough to enclose the entire patient thus avoid the truncation of data in axial slice, cupping artifacts. Accuracy of VDV is related to the object location in the center of FOV.

KEYWORDS: Cone-beam computed tomography, Field of view, Voxel density value.

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INTRODUCTION

Cone beam computed tomography (CBCT) is an advanced extra oral imaging modality. It is an imaging modality that uses a divergent pyramidal x-ray beam emitting from a fixed source to a rotating gantry to which also the assigned detector is fixed. The emitting beam is directed to the field of view (FOV) hence the residual attenuated photons strike the detector on the opposite side. [(1)]

CBCT had widespread utilization in so many fields of the maxillofacial and dental radiology that is of course due to its numerous advantages compared to multidetector computed tomography (MDCT), that the former is more economic as the cost of CBCT equipment is three to five times less than that of traditional medical CT, CBCT only requires comparatively fewer sieverts to perform a scan hence the latter is much more safer diminishing patient radiation dose [(2)].

Since it has so many benefits, including less expensive scanners with lower radiation dose, quicker acquisition times, submillimeter resolution, and it appears to provide good spatial resolution, gray density range, and contrast, as well as a good pixel/noise ratio, CBCT has been widely used for oral and maxillofacial imaging. [(3)]

The diagnostic effectiveness of CBCT can change depending on the exposure settings, the software being used, the post-acquisition changes, and the thresholding techniques used to evaluate the images. Under clinical circumstances, a variety of factors, including the FOV, can affect the perceived image quality of CBCT-based images and the capability of CBCT to display different characteristics. [(4)]

Numerous studies have been conducted to assess voxel grey values, and some have even attempted to mathematically connect them with CTs HU. They discovered that numerous variables affected grey values. However, not all factors had the same weight, and not all publications followed the same methodology. [(5)]

The exposure parameters, collimation, and scattering have an impact on HU measurements as well as the substantially lower dose, cone-shaped beam, two-dimensional receptor, lack of post-patient collimation, and FOV restriction of CBCT, among other factors. There is greater scatter radiation, noticeable beam hardening, and obvious attenuation coefficient instability. These elements will have an even greater impact on the CBCT process of HU measurements. [(6)]

According to El-Tabarany et. al [(7)], the second most important factor after machine model was the FOV, the impact of FOV should be tested after all other parameters have been fixed. When it comes to this factor, it should be done on the same machine so that most of the exposure settings may be established. [(7)]

Some studies reported that when the FOV, voxel size, and all exposure settings were fixed, altering the arrangement of the objects had a noticeable impact on the VDV. They discovered that the voxel values were greatly impacted by exo-mass. The impact varies along the FOV and is direction dependent. [(8 ,9–13)]

In some instances, the effect of FOV modification may have been studied as a single factor (Katsumata et al 2007), while in others, it may have been tested as a combined factor with voxel size (Katsumata et al 2009, Pauwels et al 2013, Oliveira et al 2014, Molteni al 2013, Dillenseger et al 2014, Rodrigues et al 2015). FOV has a considerable impact on voxel values in both scenarios. [(9–13)]

Regarding how each element affects the VDV of the CBCT, there is currently a dilemma in the literature. Up To our knowledge, there have been no comprehensive evaluations of CBCT testing the validity of the HU numbers. Additionally, its clinical importance and relative relationship between several parameters. [(7)]

Hence our systematic review aimed to accurately define the impact of FOV on CBCT (VDV). based on systematic analysis of the available literature that reported the effect of FOV on CBCT VD.

Aim of the study

The aim of the current study is to accurately define the impact of field of view (FOV) on cone beam computed tomography (CBCT) voxel density value (VDV). based on systematic analysis of the available literature that reported the effect of field of view on cone beam computed tomography voxel density value. Attention is given to size of field of view, object location inside the field of view and proper selection of the field of view and its relation the voxel density value of cone beam computed tomography.

MATERIAL AND METHODS

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards served as the foundation for this systematic review's methodology.

Protocol registration

This systematic review protocol was registered in PROSPERO by ID no: CRD42022350838.

Search methods for identification of studies

We tracked all citations related to our inquiry using three electronic databases used in the health sciences: Medline via PubMed, Embase, and the Cochrane library. The reference lists of relevant publications were manually searched to uncover research that the automatic database searches could have missed.

The PICOS question served as a guide for our search approaches inclusion/exclusion standards, Inclusion criteria:

- Studies with clear specifications of the CBCT machine used.
- Studies with clear exposure parameters of the image acquisition (mA, FOV and voxel size).
- Studies have a gold standard for comparison.

While the exclusion criteria:

- Studies with fixed FOV.
- Case studies.
- Review articles.
- Studies with fixed FOV.

Finally, when the article lacked the necessary information. The search was modified to adhere to each database's syntax requirements and the search strings were created with the assistance of two experts.

Research was done on Medline on 13 August 2022 at 10:51 a.m. and on 13 August 2022 at 11:59 on Embase libraries using PubMed search engine, and on 13 August 2022 at 11:24 on Cochrane library using Cochrane search engine.

Mesh keywords (medical scientific headings) were used as search phrases to ensure that every potential variation of the search term was found.

The search words were: ((Cone beam computed tomography) OR (cone beam computerized tomography) OR (volumetric computed tomography) AND (Field of view) OR (scan volume) OR (imaging volume) AND (voxel density value) OR (voxel value) OR (Gray scale value))

Filters were added:

Publication years: 2006-2022 CBCT

Search words were:

- Cone-beam computed tomography.
- Field of view
- Voxel density value.

The Boolean operator "AND" was then used to join the three terms after each word had been independently looked for.

The search words were: ((Cone beam computed tomography) OR (cone beam computerized tomography) OR (volumetric computed tomography) AND (Field of view) OR (scan volume) OR (imaging volume) AND (voxel density value) OR (voxel value) OR (Gray scale value))

Results were downloaded as a TXT file that included each paper's abstract and all its citations.

Our research summed in total 13405 studies, 10279 from Pub Med and 1337 from Cochrane and 1789 from Embase. 13000 duplicates digitally and manually have been removed. search in the titles excluded 120 papers, then search in the abstracts excluded 200. The manuscript was included and downloaded for further study at the second stage if the abstract at this stage was ambiguous or produced an equivocal result.85 papers out of 405 were the outcome of the second stage. The included seven research papers underwent a data extraction step in which the study was summarized in a table with the following headings: title, first author, name of the journal, year of publication, number and kind of machines used.

TABLE (1) Techniques of searching databases.

Database	**Search strategy**	Hits
MEDLINE (via PubMed)	Search #1 Cone-beam computed tomography ("cone beam computed tomography"[MeSH Terms] OR ("cone beam"[All Fields] AND "computed"[All Fields] AND "tomography"[All Fields]) OR "cone beam computed tomography"[All Fields] OR ("cone"[All Fields] AND "beam"[All Fields] AND "computed"[All Fields] AND "tomography"[All Fields]) OR "cone beam computed tomography"[All Fields])	19174
	Search #2 (("field"[All Fields] OR "field s"[All Fields] OR "fields"[All Fields]) AND ("view Beijing"[Journal] OR "view"[All Fields])	28255
	Search #3 (("voxel"[All Fields] OR "voxel s"[All Fields] OR "voxelization"[All Fields] OR "vowelized"[All Fields] OR "voxels"[All Fields]) AND ("densities"[All Fields] OR "density"[All Fields]) AND ("value"[All Fields] OR "values"[All Fields]))	771
	Search #1 AND #2 AND #3	**10279**
Cochrane	Search #1"cone beam computed tomography"	1351
	Search #2"field of view"	335
	Search #3"voxel value"	5
	Search #1 AND #2 AND #3	**1337**
Embase	Search #1((Cone beam computed tomography) OR (cone beam computerized tomography) OR (volumetric computed tomography	8,724
	Search #2 (Field of view) OR (scan volume) OR (imaging volume)	5,847
	Search #3(voxel density value) OR (voxel value) OR (Gray scale value))	1,641
	Search #1 AND #2 AND #3	**1789**

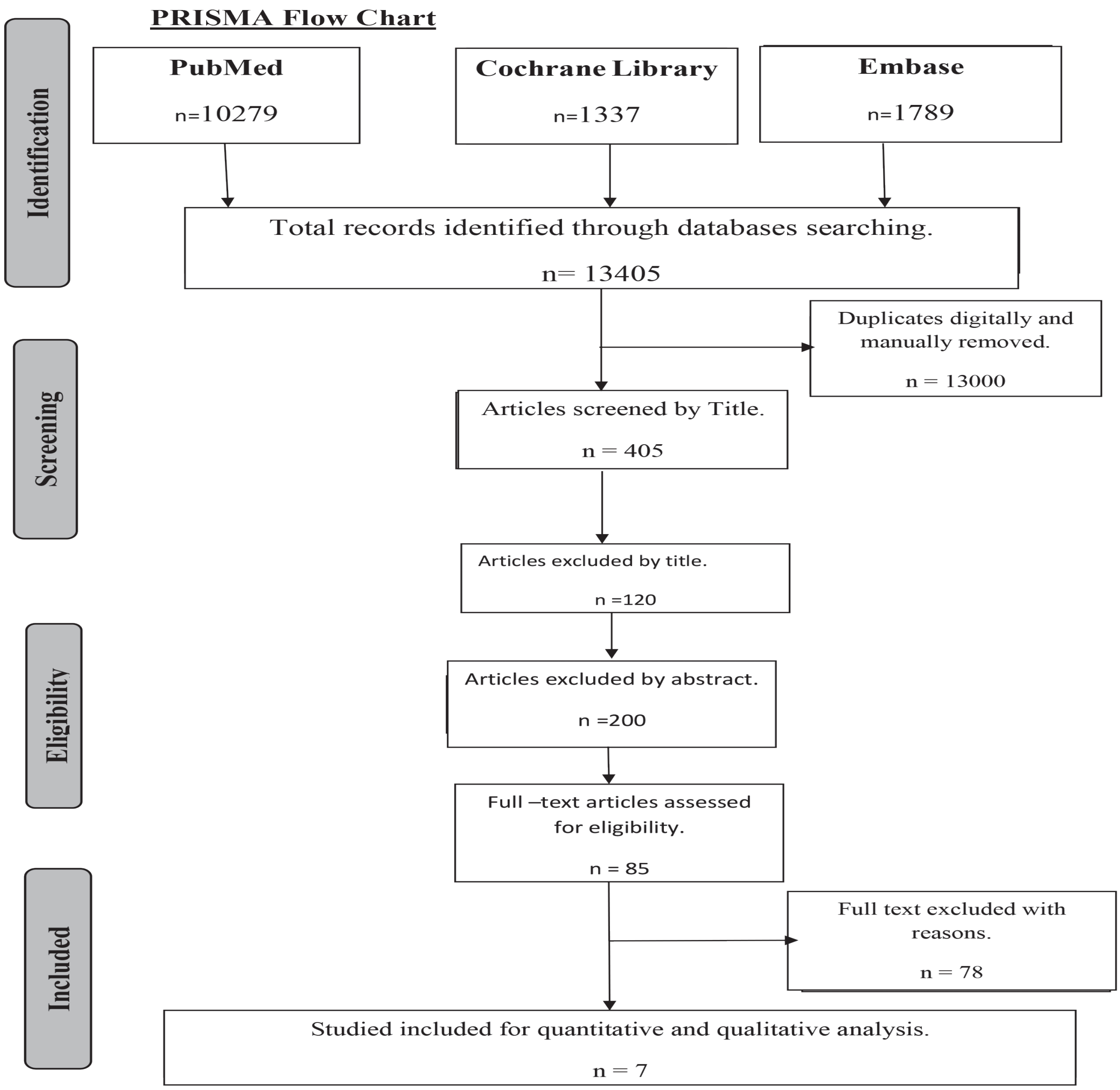
TABLE (2) Risk of bias assessment

Authors	Akitoski katasuma et al (2007)	Yoshikazu Nomura et. al (2010)	Jira Chindra-smbajareon et. al (2011)	A Parsa et.al (2013)	Andreia Fialho Rodrigues et.al (2015)	Abbas Shokri et.al 2018	Katrina Y T Seet et al, 2009
Criteria							
Introduction							
Objectives (states specific objectives and hypothesis?)	√	√	√	√	√	√	√
Methods							
Study design (presents key elements of study design early on?)	√	√	√	√	√	√	×
Setting (describes relevant dates, setting, and location?)	√	√	√	√	√	√	√
Participants (gives eligibility criteria?)	×	×	×	×	×	×	×
Bias (efforts to address potential bias described?)	×	×	×	×	×	×	×
Study size (method to retrieve study size explained? Was it adequate?)	√	×	√	√	√	√	×
Statistical methods (all statistical methods described? Appropriate for data?)	×	√	√	×	√	√	×
Results							
Participants (numbers at each stage described?)	√	√	√	√	√	√	√
Outcome data (numbers of outcome events reported?)	√	√	√	√	√	√	√
Discussion							
Limitations (were limitations including potential bias discussed?)	×	√	√	√	√	√	×
Interpretation (were cautious interpretations discussed?)	√	√	×	√	√	√	
Generalizability (study has external validity?)	×	×	√	√	√	√	√
Other *Information*			×	×	×	×	×
Funding (was source of fundingoutlined? If so, bias with funders?)	×	x	√	×	x	x	√
Total Score	8 of 12	10 of 12	10 of 12	10 of 12	10 of 12	10 of 12	6 of 12
Total percentage	66%	83 %	83 %	83 %	83 %	83 %	50%

TABLE (3): Results.

No	Title	1st author	Year	Journal	No. & type of machine(s)	Exposure parameters	Summary
1	Effects of image artifacts on gray-value density in limited-volume cone-beam computerized tomography	Akitoshi Katsumata	2007	Oral Surg Oral Med Oral Pathol Oral Radiol Endod	2CBCT systems: 1.3DX FPD limited volume CBCT system,2.3DX Accuitomo II and (MSCT) scanner	For the 2CBCT systems: Rot. arc =360, T=17s, mA=8mA, Kvp=80Kv, pixels = 0.125. For MSCT system: mA =200mA, Kvp=120Kv and T=0.7 s/rotation. The pixel size = 0.3 mm	The difference in relative densities between the lingual and buccal soft tissues in an area adjacent to the mandible was used to assess the effect of projection data discontinuity–related abnormalities in limited-volume CBCT images of the jaws. When more objects were presented outside the FOV, the intensity of the artifacts increased. When compared to the II system, the FPD CBCT images produced in this study showed less artifact influence, especially when a larger FOV was chosen.
2	Reliability of voxel values from cone-beam computed tomography for dental use in evaluating bone mineral density	Yoshikazu Nomura	2010	CLINICAL ORAL IMPLANT RESEARCH	3D Accuitomo with image intensifier and a Somatom Sensation 64	3D Accuitomo operated at First setting Kvp= 80Kvp, mA =6mA, second setting, Kvp= 70, mA =7.8 Exp. T. =17 s. for each A Somatom Sensation 64 with kV =120, mA =140mA, FOV= 50mm	The CT numbers of MSCT and the CBCT voxel values showed a strong association. There was a definite potential of calculating CT numbers and BMD using the voxel values from the CBCT images, even though this was an in vitro study with presumed perfect circumstances for measuring voxel values; nonetheless, the connection was not totally linear and should be further investigated.
3	Correlation Between Pixel Values in a Cone-Beam Computed Tomographic Scanner and the Computed Tomographic Values in a Multidetector Row Computed Tomographic Scanner	Jira Chindasombatjaroen	2011	J Comput Assist Tomogr	CBCT system: Alphard Vega 3030 and a MDCT Light Speed QX/i	The MDCT scan performed with a pixel size = 0.39 mm^2, Kvp= 80, 100Kvp and mA=100, 120, 150, 170, and 200mA. The CBCT scan was performed with Rot. Arc=360, voxel size =0.39 mm3. Kvp= 80 and 100 Kvp at T. = 17-s and mA= 6, 7, 9, 10, and 12,102, 119, 153, 170 and 204 mA.	There are a strong correlation between the CT values from an MDCT scanner and the pixel values from a CBCT scanner at the center of the FOV, and a linear connection were discovered for each parameter. Consequently, one may transform to a linear function. pixel value from the CT to the CBCT equipment utilized in this research. values. The pixel value was used to calculate these predicted CT values. Improved CBCT might result in more accurate diagnosis and treatment planning.
4	Influence of cone beam CT scanning parameters on grey value measurements at an implant site	A Parsa* ,1, N Ibrahim1, B Hassan1	2013	Dentomaxillofacial Radiology	three CT modalities: two CBCT systems: 1. NewTom 5G®, 2. Accuitomo 170®, and a (MSCT)	Tom 5G New operated at mA =0.57mA and Kvp =110Kvp, voxel sizes between 0.15 and 0.30 mm and four FOVs (80*80mm, 120*80mm, 150*120mm, and 180*160 mm)Accuitomo 170 operated at Kvp=90 Kvp, mA= 5mA scan time= 9 to 30.8 seconds, Rot.arc=360 or 180) and nine FOVs (40*40 mm, 0.08 mm Vs, 60*60 mm, 0.125 mm Vs, 80*80 mm, 0.160 mm Vs, 100*50 mm, 140*50 mm, 140*100 mm, 170*50 mm, and 170* 120 mm 0.25 mm for the remaining FOVs) Multislice CT worked with isotropic voxel =0.67mm^3, Kvp =120, mA =222, T. =1.128 s	The device and scanning parameters have an impact on the grey-level readings from CBCT images. Both the Accuitomo 170 and the NewTom 5G may drastically alter the grey value readings, and in the case of the latter, the number of projections can have an impact. So, while examining voxel grey values from CBCT to determine bone mineral density, it is important to consider the scanning parameters.

5	Use of Gray Values in CBCT and MSCT Images for Determination of Density: Influence of Variation of FOV Size	Andreia Fialho Rodrigues	2015	Implant dentistry	Two machines: an i-CAT and a Somatom Spirit device	I-CAT used with kV =120Kvp and mA =3–8mA, Rot. T= 26.9-, and a voxel size = 0.250 mm. The Somatom Spirit device scan was at kV= 130Kvp and mA. = 70mA	This study demonstrated that the FOV size has a substantial impact on the grey values acquired during CBCT exams after correcting for exomass, object placement inside the FOV, and mass in the slice. Despite slight variances, the grey values obtained in MSCT with various FOV diameters showed statistically significant differences to ascertain whether the discrepancies identified in the studies have a major impact on the clinical processes, more research should be conducted.
6	Effect of field-of-view size on gray values derived from cone-beam computed tomography. compared with the Hounsfield unit values from multidetector computed tomography scans	Abbas Shokri	2018	Imaging Science in Dentistry	1 MDCT system and two CBCT systems: - 1. NewTom 3G 2. Cranex 3D	NewTom 3G system. used voxel size 8 cm x 8 cm, 0.2 mm, 13 cm x 16 cm, 0.3 mm at mA= 3-8, Kvp= 110 Using Cranex 3D system. Used FOVs (4 cm x 6 cm, 0.136 mm voxel size) and big (6 cm x 8 cm, 0.2 mm voxel size) at mA =5 mA and Kvp =90 Kvp. The gold standard for MDCT is the Somatom Spirit with FOV. =13 cm * 16 cm At Kvp =110Kvp and mA =70mA	The MGVs of the materials evaluated in this study were dramatically altered by the size of the FOV employed in CBCT systems, except for Cerabone in the Cranex 3D system. By comparing their MGVs, the two CBCT systems could tell the three different kinds of bone replacements apart. Regarding the MGVs of the 3 bone replacements examined in this investigation, the Cranex 3D system with a narrow FOV demonstrated a statistically significant connection with MDCT results.
7	The effects of field-of-view and patient size on CT numbers from cone-beam computed tomography.	Katrina Y T Seet	2009	Institute of Physics and Engineering in Medicine	One CBCT scanner and one CT system (pCT)	KV CBCT at a low dose (40 mA, 125 Kvp, and 10 mAs) and standard dose (80 mA, 125 Kvp, and 25 mAs), reconstructed with the 512 × 512 matrix in axial slices. Planning CT (pCT) studies were acquired on a CT. at 120 kV, 85 mA and 3 mm slice spacing.	In this investigation, CBCT was used to capture images of uniform phantoms utilizing a variety of settings. Cupping artefacts are known to appear when imaging phantoms with a FOV smaller than the phantom size. Due to the modest data truncation, imaging even in full-fan mode with a FOV equal to the phantom size resulted in CT statistics that were lower than anticipated. It was crucial to make sure that the FOV encompasses the complete patient or phantom. The FOV and phantom size are the main variables that affect the accuracy of CT numbers. While imaging in full-fan mode, the FOV should be both modest to enhance spatial resolution and large enough to prevent scattering material from being truncated. However, depending on the size of the phantom, imaging with a FOV D in half-fan mode exhibits CT variations of various intensities. They advised doing the system's initial calibration with a phantom that is the same size as the object that will be photographed. Due to its vulnerability to increased dispersion and hence erroneous representation of material density at the current stage of OBI development, CBCT was not appropriate for adaptive planning.



DISCUSSION

Cone beam computed tomography is a cutting-edge extraoral imaging technique that is extensively used in the disciplines of maxillofacial and dental radiology. [14]

The choice of FOV is one of the most significant constraints on radiation dosage and image quality. In Implantology, depending on how many and where the prospective implant is, a different FOV size will be used. As of now, the impact that FOV and other scan parameter choices have may affect measurements of the grey value made using CBCT is yet unproven. [15]

Several studies have been conducted to analyze CBCT acquisition parameters correlation with VDV., Katsumata et al. [16] tested three machines (3DX Accuitomo image intensifier II and 3DX flat panel detector FPD limited volume CBCT systems and Whole-body MSCT scanner. All other parameters, including voxel size, were fixed.

This study concluded that the FOV had a distinct, significant impact on VDV. [16]

Furthermore, Katsumata et al, [17] used a single CBCT machine, a newly developed flat panel detector CBCT system (Alphard Vega) with four FOV sizes to examine the impact of switching between them on the difference in voxel values. The machine used for this work, however, employed various voxel sizes for various FOVs. It was impossible. However, it was shown that varied voxel sizes in addition to varying FOV sizes have a considerable impact on voxel grey values. [17]

In addition, Seet et al. [19] investigated images of uniform phantoms that were acquired with kV CBCT utilizing various parameters. They discovered that the choice of field-of-view, object size and filter type have the most influence on VDV from CBCT. Regardless of the size of the phantom, image capture in half-fan mode consistently yielded better accurate VDV. They concluded that FOV needed to be both tiny to enhance spatial resolution and large enough to prevent scattering material from being truncated. [19]

Moreover, Parsa et al [15] used one MDCT and two CBCT devices in their research. The smallest and largest accessible voxel sizes were employed, along with all FOVs offered by both machines. They concluded that the chosen FOV should contain the data required for planning a diagnosis and course of therapy. The ideal FOV must be chosen for each individual patient because of the wide range in size of individuals. The most crucial scanning aspect for reducing radiation exposure and improving image quality was still the size of the chosen FOV. Their findings demonstrated that this component affected the variability of VDV in both CBCT systems. Both the Accuitomo 170 and the NewTom 5G may drastically altered the grey value readings, and in the case of the latter, the number of projections could have had an impact. The scanning parameters should be considered when examining VDV from CBCT to determine bone mineral density. [15]

In some instances, the effect of FOV modification may have been studied as a single factor (Katsumata et al 2007), while in others, it might have been tested as a combined factor with voxel size. FOV had a considerable impact on VDV in both scenarios. Pauwels et al [12] omitted to disclose the voxel size, which made it unclear whether the study's findings were the consequence of a single component or a combination. [7,9–13].

Bryant et al. [8] claimed to fix all exposure parameters and utilize a single machine. However, the FOV height was provided inexactly and wasn't outright claimed to be rectified. [8]

They discovered that VDV were greatly impacted by exo-mass. The impact varies along the FOV and is direction dependent. VDV were found to be high close to the exo-mass and to progressively decline until they reached the midpoint, which was the most correct number, before continuing to decline till the opposite side of the FOV with a comb-like artefact. [8]

Furthermore, Nomura et al, [18] selected materials with strong X-ray absorption for their non-target items and positioned them in the FOV's center. These materials could keep the CBCT projection data's sensitivity correction at a consistent level. This explained why in the experiment by Nomura et al., the pixel values in the target region were linearly associated with the amount of x-ray absorption: the positioning of materials with high x-ray absorption levels at the center of the FOV might have impacted the pixel values. [18]

In one word, the impact of FOV on VDV is one of the critical factors concerning the image quality and patient radiation dose; it is a must for clinician to choose the smallest possible FOV and to adjust the place of the ROI in the center of the FOV to avoid intensity variability in the gray scale value of the resultant image.

CONCLUSION

After completing this systematic review, under study, which are as follows.

1. The field of view is one of the most important factors influencing VDV of CBCT and hence image quality.
2. Regarding the size of the field of view, we have concluded that.
    a) FOV size is directly proportional to the amount of radiation to which the patient is exposed.
    b) The FOV should be small to maximize spatial resolution and large enough to enclose the entire patient thus avoid the truncation of data in axial slice, cupping artifacts.
    c) The intensity of the artifacts increased when more objects (exomass) were located outside the FOV.
    d) Accuracy of VDV is related to the object location in the center of FOV.

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