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ACCURACY OF CONE BEAM COMPUTED TOMOGRAPHY TO DETERMINE JAW BONE DENSITY AS COMPARED TO MICRO CT: A SYSTEMATIC REVIEW AND META-ANALYSIS

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Abstract

BACKGROUND:

Evaluation of Bone Density (BD) is crucial for the diagnosis of disorders related to bone loss and for determining the quality of bone needed for different dental operations. We are familiar with the fact that computed tomography (CT) has been used in assessment of bone quality, for a quite some time, but due to the known risks CT has been increasingly replaced by Cone Beam Computed Tomography (CBCT). Extensive researches have been conducted to check the reliability of CBCT because it offers sufficient image quality at a reduced exposure dose when assessing mineralized tissues. The goal of the current systematic study is to assess how accurate CBCT is at estimating the BD of jaw in comparison to CT.

METHODS:

A thorough evaluation of the literature, including works published through December 2022 on PubMed and Google Scholar, was conducted. The English-language articles that were accessible were included.

RESULTS:

Following the application of inclusion and exclusion criteria, a total of 5 observational studies assessing the accuracy of CBCT were included in the study. This showed that considering the reduced radiation dose, increased resolution due to small volumes, and accuracy at par with CT, CBCT can henceforth be used to evaluate the density of jaw bone as accurately as CT.

CONCLUSION:

The inference that can be drawn from present review is that small volume CBCT can be used to evaluate jaw BD.

Keywords: Systematic review, meta-analysis, CBCT, CT, jaw bone density, micro-architecture.

INTRODUCTION:

Bone quality is evaluated using X-ray imaging, either subjectively with or without reference images or objectively by quantifying jawbone.[1] This phrase is frequently used in the context of dento-maxillofacial medicine to describe the clinical assessment of diseases that impact the mandible. Computed Tomography (CT) was one of the methods that provided precise 3D evaluation and measures bone density in Hounsfield units, crucial for dental implant surgery.[2] While micro-CT is accurate for trabecular bone analysis, its high radiation limits the clinical use.[3] In dentistry today, CBCT is becoming more and more preferred over MSCT for evaluating mineralized tissues because it offers sufficient image quality at a lower radiation dose.[4] The present systematic review explores CBCT's potential in clinically assessing jawbone trabecular microarchitecture, correlating parameters with micro-CT images.[4] This systematic review's goal was to direct future study in this field because there isn't much literature on the subject.[5]

FOCUSED RESEARCH QUESTION:

"Is the accuracy of CBCT better in evaluating density of jaw bone to determine micro architecture of bone as compared to Micro CT?"

AIM:

The goal of this research was to conduct a systematic review focused on the evaluation of "accuracy of Cone beam computed tomography to determine jaw BD in comparison to Micro CT".

METHODOLOGY:

"The present systematic review was registered at the National Institute for Health (NIH) Research PROSPERO International Prospective Register of Systematic Reviews (reg.no.:

CRD42023459673)". "This research protocol is designed according to the Preferred Reporting Items for Systematic Review and Meta-Analyses guidelines (PRISMA) 2021".

Search Strategy

Using databases from PubMed, Cochrane, and Google Scholar, a thorough literature search was conducted until December 2022. The inclusion and exclusion criteria outlined in (Table 1) were followed in selecting the articles. Two reviewers separately examined each recognized study's title and abstract to determine eligibility. Every study that satisfied the criteria for eligibility was chosen for full-text viewing. The study included full-text papers that met the eligibility requirements, processed them for data extraction, and noted the reasons for exclusion. Reviewers reviewed lists at each stage, and if there was a disagreement, a third reviewer's input was sought before final choices on inclusion or exclusion were made.

Data Extraction

Using a consistent electronic form, the data were independently extracted from the full-text articles that were chosen for inclusion. The incorporated research yielded the following data extractions: Authors name, Year of study Place of study, Study Design, sample size, Intervention parameters, comparator parameters, Outcomes, Conclusion.

Statistical Analysis

"Review Manager (RevMan) 5.3 was used for statistical analysis. The primary outcome measure was standardized mean difference (SMD) for mean micro shear bond strength at 95% confidence intervals (CIs), $P<0.05$ using random effect model. Heterogeneity was assessed by the Q test, for $p < 0.1$, as well as by the I2 test". For each outcome evaluated, a funnel plot was created to identify publication bias in studies with more than ten participants.

RESULTS :

The PRISMA statement flowchart, summarizes the selection process, as shown in Figure 1. After screening on PUBMED and GOOGLE SCHOLAR, a total of 105 articles were found. Of these, 24 duplicate articles were eliminated. The remaining 81 articles were then screened, and of these, 34 articles did not have free full texts available. The 47 full text articles that were left were then evaluated for eligibility, and 42 of them did not meet the inclusion criteria. As a result, the remaining 5 free full texts were included for qualitative analysis, out of which one was excluded because its variables did not match the others'.

Study Characteristics:

The characteristics of 5 studies are listed in table 2. All the studies were observational studies[2,4,6-8]. Two studies were conducted in Belgium, and the others were conducted in Italy, Japan and, South Korea. The samples in the study used were the different section of jaw bones. The meta-analysis was composed of four of the five studies. Studies differ significantly in terms of parameter variability. This might be explained by the variation in the FOV, voltage, current, voxel sizes, number of rotations in both intervention group and comparison group. Four out of 5 studies have mean values of bone volume fraction (BV/TV) and trabecular bone thickness (Tb.Th) as their primary outcomes[2,4,6-7.] The mean values of Bone specific density (BS/TV), Bone specific surface (BS/BV), trabecular bone pattern (Tb.Pf), and trabecular separation (Tb.Sp) were evaluated as the secondary outcome. The outcome measures differed between the first study and rest of the studies, as in former they used the original values instead of the mean values unlike the rest of the studies.

Assessments of the risk of bias and quality:

Quality assessment showed a huge variation across the included studies. "The risk of bias and the methodological quality of the included papers was evaluated using the simplified version of the NIH Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies".[8] The parameter of study examines different levels of the exposure, sufficient timeframe, assessed more than once, and loss to follow-up 20% were considered as cannot be determined. Only one of the five studies received a high quality rating,[6] while the remaining 4 studies were rated as fair quality studies.[2,4,7-8] This fair quality was mostly caused by the lack of sample size justification, prior disclosure of the exposure of interest being measured, and assessor blinding.

Synthesis of results:

A total of 4 studies[2,4,6-7]fulfilled the inclusion criteria for quantitative analysis. Subsequently, a total of four meta-analyses were performed separately to measure the accuracy cone beam computed tomography (CBCT) for structural analysis of alveolar bone in comparison with and micro-CT.

The pooled outcomes from 4 studies[2,4,6-7], with a total sample size of 102 each in the CBCT and micro-CT group, the standardized mean difference (SMD) value for BV/TV using "random effect model" was 2.16 [0.79, 3.52] and showed a statistically significant difference ($p= 0.002$) between the CBCT and micro-CT group favouring the CBCT group [Tau^2 =1.62, Chi^2 =29.56, I^2 = 90%], (Table 1).

The pooled outcomes from 3 studies[2,6,4], with a total sample size of 82 each in the CBCT and micro-CT group, showed a SMD value for BS/BV using "random effect model" as -1.46 [-2.40, -0.52] and a statistically significant difference ($p= 0.002$) between the CBCT and micro-CT group favouring the micro-CT group [Tau^2 =0.46, Chi^2 =6.21, I^2 = 68%], (Table 2).

The pooled outcomes from 3 studies[2,4,6], with a total sample size of 82 each in the CBCT and micro-CT group, SMD value for Tb.Sp using "random effect model" was 0.75 [0.02, 1.48] and was statistically significant ($p= 0.04$) between the CBCT and micro-CT group favouring the CBCT group [Tau^2 =0.25, Chi^2 =4.88, I^2 = 59%], (Table 3).

The pooled outcomes from 3 studies[2,4,6], with a total sample size of 82 each in the CBCT and micro-CT group, showed SMD value for Tb.Th using "random effect model" as 4.42 [1.28, 7.56] and a significant difference ($p= 0.006$) between the CBCT and micro-CT group favouring the CBCT group [Tau^2 =5.40, Chi^2 =19.07, I^2 = 90%], (Table 4).

DISCUSSION

Bone density (BD) is the quantity of bone tissue.[9] Assessment of jaw BD can be taken into consideration and is necessary, in lots of scientific conditions inclusive of oral and/or systemic diseases, implant planning, healing assessment and follow-up. BD varies at some stage in areas of the jaws and can be laid low with many elements together with osteoporosis.[9]

The limited data that is currently available about the diagnostic accuracy of CBCT was examined in this systematic review for determining jaw BD in invitro samples. In the 5 studies assessed we compared two modes of diagnostic aids for assessing the jaw BD.

To the best of the authors' knowledge, this is the first comprehensive analysis comparing CBCT against CT's ability to assess the density of jaw bone. Criteria's like BV/TV, Tb.Th, BS/TV, BS/BV, Tb.Pf, and Tb.Sp were assessed.[3] A previous systematic review has summarized the accuracy of the same CBCT against CT in determining low mineral bone density.

Percentage bone volume, often referred to as BV/TV is an important parameter in the study of bone health, as it provides information about the density and composition of bone tissue.[2] Tb.Th within the jaw bone, like in other parts of the body, can vary among individuals and may change over time due to factors such as aging.[2] A healthy trabecular bone structure is important for maintaining the structural integrity of the jaw and supporting the teeth. Both these parameters have been taken into account in 4 out of 5 studies. Amongst which these values are higher in group CBCT in 3 of the 4 analysis.

The secondary outcome in this review includes BS/TV which is the ratio of surface area to total volume measured, it is an important parameter as it helps to calculate the tooth support, chewing functions, facial structure. The other parameter measured is the BS/BV which is the ratio of solid surface to volume measured in 3D within the VOI. It is Useful basic parameter for characterizing the thickness and complexity of structures. Next one is the Tb.Pf which determines the bone strength and its flexibility. And the last parameter taken into account is the Tb.Sp which is important in assessing bone health because it can provide insights into the density and integrity of trabecular bone. Amongst all these microarchitecture parameters only the value of BS/TV was higher in CT rest all the parameters were showed greater values in group CBCT.

CBCT scans are being used by dentists more often in dental practices, particularly for implant planning in patients who are edentulous.[5]

When it comes to advantages over multislice CT, CBCT is superior. First off, CBCT uses comparatively modest effective radiation doses. Second, the resolution level is reportedly higher. Third, the accuracy of linear measurements using CBCT has been reported to be high.[7] Fourth, the ablity to clearly identify fine anatomical structures like accessory mental foramina and a bifid mandibular canal in the mandibular ramus. Fifththe small size of the CBCT device makes it use effective in the dental practice. Sixth, when small-volume CBCT was compared with large volume CBCT, lower effective radiation doses and a higher resolution were achieved with the former. The volume of CBCT should be selected according to the purpose of diagnostic imaging.

Numerous techniques are employed in research to evaluate BD and quality, but for the foreseeable future, dual-energy X-ray absorptiometry (DXA) is probably going to stay the standard method in clinical practice for the majority of patients.[10]

The BMD determined by DEXA and the HU calculated using automatic exposure control by CT show a positive connection. To detect patients with poor BMD, HU reference thresholding can be implemented to all standard CT scans. Because CT is a widely used, accessible, repeatable, and trustworthy method for determining HU values, it may be helpful in the opportunistic screening of individuals with lower BMD who may then be referred for DEXA and further treatment.[11]

In recent years, the daily use of CBCT scans by dentists has increased. Dental CBCT has lower radiological doses compared to conventional CT scans, and equally accurate CBCT studies can be used to identify patients with low BMD without additional tests (eg, DEXA) and refer these patients for further follow-up.[10]

We would recommend that more research be done to examine if CBCT could be used as an adjuvant tool for evaluating jaw BD, as there is currently insufficient data to support this theory.

CONCLUSION:

Considering the reduced radiation dose, increased resolution due to small volumes, accuracy at par with CT, CBCT can henceforth be used to evaluate jaw BD as accurately as CT.

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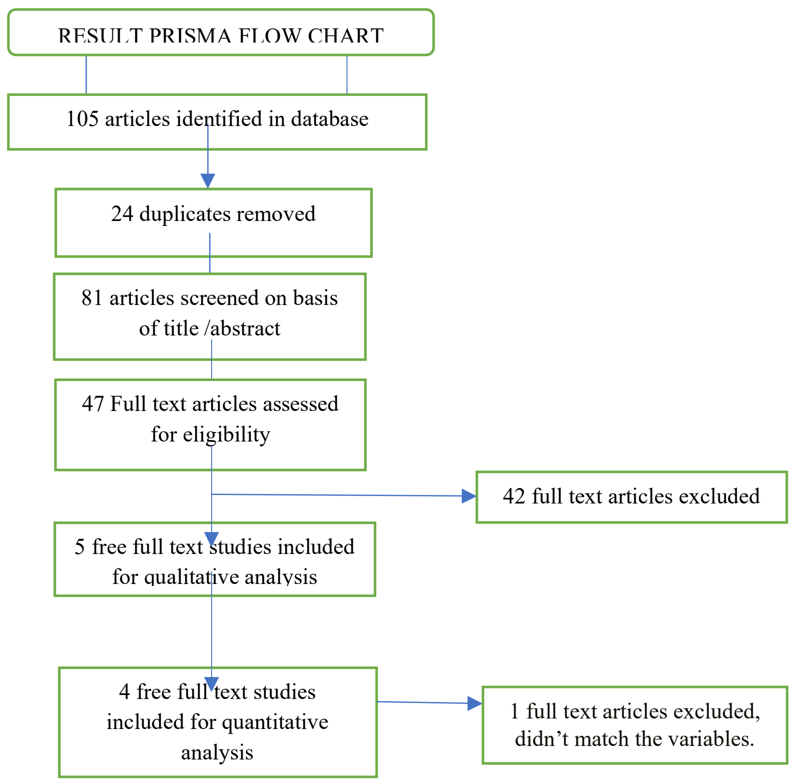
Figure 1. Flowchart of Selection of Studies
Table 1-Forest plot of the pooled analysis comparing CBCT and micro-CT for Bone Volume Fraction.
Table 2-Forest plot of the pooled analysis comparing CBCT and micro-CT for Bone surface density.
Table 3-Forest plot of the pooled analysis comparing CBCT and micro-CT for Trabecular Separation
Table 4-Forest plot of the pooled analysis comparing CBCT and micro-CT for Trabecular thickness

Figure 1: Flowchart of Selection of Studies



Bone Volume Fraction

	CBCT			micro CT				Std. Mean Difference	
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI	Year
Dessel J 2013	53.74	5.69	8	34.39	5.41	8	20.9%	3.30 [1.66, 4.94]	2013
Cassetta M 2014	1,053.31	490.15	20	744.35	366.7	20	28.2%	0.70 [0.06, 1.34]	2014
Kim J 2015	49.32	12.86	68	18.53	8.17	68	28.9%	2.84 [2.36, 3.32]	2015
Dessel J 2017	44.26	7.5	6	30.87	4.12	6	22.0%	2.04 [0.53, 3.55]	2017
Total (95% CI)			**102**			**102**	**100.0%**	**2.16 [0.79, 3.52]**	

Heterogeneity: Tau² = 1.62; Chi² = 29.56, df = 3 (P < 0.00001); I² = 90%
Test for overall effect: Z = 3.10 (P = 0.002)

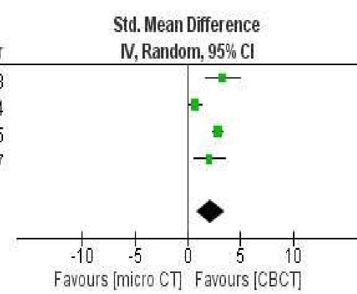


Table 1-Forest plot of the pooled analysis comparing CBCT and micro-CT for Bone Volume Fraction.

Bone surface density

Study or Subgroup	CBCT Mean	CBCT SD	CBCT Total	micro CT Mean	micro CT SD	micro CT Total	Weight	Std. Mean Difference IV, Random, 95% CI	Year
Dessel J 2013	4.4	0.46	8	6.61	1.32	8	25.7%	-2.11 [-3.41, -0.82]	2013
Kim J 2015	1.6	0.26	68	2.85	0.94	68	45.6%	-1.80 [-2.20, -1.40]	2015
Dessel J 2017	3.78	0.42	6	3.92	0.38	6	28.7%	-0.32 [-1.47, 0.82]	2017
Total (95% CI)			**82**			**82**	**100.0%**	**-1.46 [-2.40, -0.52]**	

Heterogeneity: Tau² = 0.46; Chi² = 6.21, df = 2 (P = 0.04); I² = 68%
Test for overall effect: Z = 3.03 (P = 0.002)

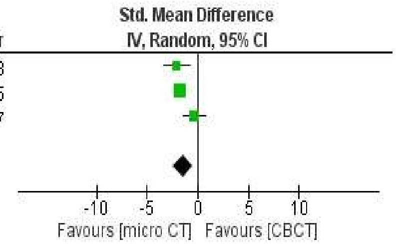


Table 2-Forest plot of the pooled analysis comparing CBCT and micro-CT for Bone surface density.

Trabecular Separation

Study or Subgroup	CBCT Mean	CBCT SD	CBCT Total	micro CT Mean	micro CT SD	micro CT Total	Weight	Std. Mean Difference IV, Random, 95% CI	Year
Dessel J 2013	0.64	0.2	8	0.54	0.18	8	27.2%	0.50 [-0.50, 1.50]	2013
Kim J 2015	1.1	0.26	68	0.83	0.17	68	49.0%	1.22 [0.86, 1.59]	2015
Dessel J 2017	0.93	0.31	6	0.91	0.18	6	23.8%	0.07 [-1.06, 1.20]	2017
Total (95% CI)			**82**			**82**	**100.0%**	**0.75 [0.02, 1.48]**	

Heterogeneity: Tau² = 0.25; Chi² = 4.88, df = 2 (P = 0.09); I² = 59%
Test for overall effect: Z = 2.02 (P = 0.04)

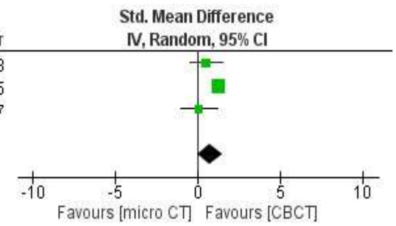


Table 3-Forest plot of the pooled analysis comparing CBCT and micro-CT for Trabecular Separation

Trabecular Thickness

Study or Subgroup	CBCT Mean	CBCT SD	CBCT Total	micro CT Mean	micro CT SD	micro CT Total	Weight	Std. Mean Difference IV, Random, 95% CI	Year
Dessel J 2013	0.42	0.01	8	0.19	0.01	8	10.2%	21.75 [13.01, 30.48]	2013
Kim J 2015	49.32	12.86	68	18.53	8.17	68	47.0%	2.84 [2.36, 3.32]	2015
Dessel J 2017	44.26	7.5	6	30.87	4.12	6	42.8%	2.04 [0.53, 3.55]	2017
Total (95% CI)			**82**			**82**	**100.0%**	**4.42 [1.28, 7.56]**	

Heterogeneity: Tau² = 5.40; Chi² = 19.07, df = 2 (P < 0.0001); I² = 90%
Test for overall effect: Z = 2.76 (P = 0.006)

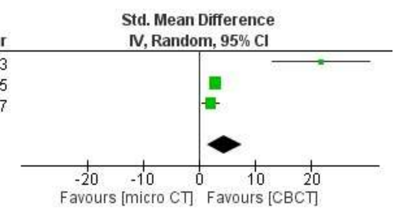


Table 4-Forest plot of the pooled analysis comparing CBCT and micro-CT for Trabecular thickness