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A Clinician Approach to Assess the Accuracy of Cone Beam Computerized Tomography in Dental Implant Placement

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Abstract

Dental radiography is widely used by clinicians in dentistry, whereas in radiology continuously and rapidly developing devices have become integral to dental practices. The conventional dental x-rays have limited diagnostic value as being two-dimensional (2D) depictions of three-dimensional (3D) oral cavity. The Cone Beam Computed Tomography (CBCT) currently in practice, is considered to be gold standard for diagnostic assessment in orofacial dentistry. CBCT enables a precise 3D image of the orofacial region and provides more accuracy in evaluating the architecture, contouring and density of the bone and soft tissues. It has wide implementation in implant dentistry. This research article evaluates the accuracy of the diagnostic imaging technique CBCT for postoperative accuracy.

In 22 patients, 136 implants were replaced for missing teeth with equal males to female ratio. 56 implants were placed in maxilla and 80 in mandible. The age of the group was between 45 to 60 yrs. Variety of implant systems with endosseous implants were replaced to accommodate and facilitate the missing teeth. All patients underwent CBCT Scan before and also within 06 months of implant placement. Standard torque of 25 Newton and 35 Newton were applied to stabilize the implants in the osteotomy cut in maxilla and mandible respectively. The patients were given prosthetic part after securing interim period of osseointigration with prefabricated available abutments. The results were evaluated preoperatively and post operatively on CBCT image for measurements of bone height and width at different level along with implant size variations in CBCT images. It has been significant dimensional changes observed in bone height measuring by Shapiro-Wilk test for normality ($P = 0.0033$, two-tailed), indicating a small but meaningful change in bone height following surgery. In coronal width using a paired t-test, no statistically significant difference pre- and postoperative measurements ($P = 0.9232$) was noted likewise in apical width ($P = 0.9232$) indicating stability after surgery. The implant height and width post CBCT images measured comparative to actual implant size, they are statistically significant ($P < 0.0001$) in both directions, indicating a slight overestimation in both height and width by CBCT, underscoring the need to account for these variations in clinical practice.

Keywords: Jawbone, Alveolar Bone, Dental implants, CBCT, Diagnostic Imaging,

Abbreviations and acronyms: 2D image (Two- Dimensional imaging), 3D (Three- Dimensional imaging), CBCT (Cone Beam Computed Tomography), CT (Computed Tomography), CADCOM (Computer-aided Design & Computer-aided Manufacturing) EMI (Electromagnetic Interference Laboratory), ALARA (As Low as Reasonably Achievable), MRI (Magnetic resonance imaging), HU (Hounsfield units), IBM (International Business Machines Corporation).

1. Introduction

Dental implant treatment planning was achieved during old days from clinical assessment, dental study cast analysis, along with 2D imaging (apical and panoramic X-Rays). This method has limitations and doesn't give accurate data hence an implant may be placed close to the vital structures, such as a nerve, artery, or sinus cavity [1]. The implant placement planning is important for its success [2].

Radiography is widely used by clinicians in dentistry for diagnosis & management [3], whereas, continuously and rapidly developing devices in radiology are becoming integral part to dental practice [4] . The Cone Beam Computed Tomography (CBCT) is considered to be gold standard for diagnostic assessment in orofacial dentistry [5]. The conventional dental x-rays have limited diagnostic value as two-dimensional (2D) depictions of three-dimensional (3D) oral cavity [6]. CBCT enables a precise 3D image of the orofacial region and provides more accuracy in evaluating the architecture, contouring and density of the bone and soft tissues. Thus it gives accurate image assessment in axial, sagittal and coronal directions, comparable to conventional radiological diagnostic techniques [7].

Successful dental implants placement for lost teeth needs detailed information of surrounding bone, adjacent anatomical structures and future osseointegration information regarding surgery. CBCT device applies a purpose in planning and placement of dental implants and also gives postoperative assessments of healing and possible complications. In inaccurate implant placement, the clinician compromises biomechanics, esthetic and abutment placement with suboptimal results or implant failure. CBCT is not only implemented in oral surgery but also being used in orthodontics, periodontology, and endodontics. The precision and quality of the image has placed CBCT as foundation for dental implants placement [7, 8]

1.1. Cone-Beam Computed Tomography (CBCT)

Computed Tomography scan was invented in 1967 by Sir Godfrey Hounsefield at EMI Central Research Laboratories, using X-Rays technology [9]. Brain CT was first performed in Wimbledon, England in 1971 and was announced after a year [10]. The CT scan gives high radiation dose to patient and that is why the system has limited utility in maxillofacial area. Cone Beam Computed Tomography (CBCT) was invented by Sir Godfrey N. Hounsefield later. Initially developed for angiography in 1982, later on applied for maxillofacial imaging. In late 1990's, the clinical systems were produced to use in dental offices with 3D display of the orofacial region within the ALARA principle (As Low as Reasonably Achievable). A cone-shaped X-rays beam makes CBCT to cover the require area to scan with a single rotation of the X-rays beam and the detector [11].

In clinical dentistry of implantology, CBCT has extreme diagnostic value for positioning of implant and success of implant placed [12]. With the invention of computer-aided design/computer-aided manufacturing (CAD/CAM) system, it has provided the state of art diagnosis and surgical implants planning and delivery of their prostheses. The CBCT and CAD/CAM working together providing ideal

treatment planning and postoperative success [12]. The CBCT values its price, radiation dose, clinical information, and treatment success predictability in oro-maxillofacial patients [13].
This clinical paper aims to describe the relative accuracy of the diagnostic CBCT for bone prediction to dental implants placement and their success.

2. Materials and methods

This is a randamised interventional study of 22 implants (one implant from each patient) whereas 136 implants from three different brands were placed in 22 patients with equal male to female ratio. Data was collected at maxillofacial surgery dental clinic during June 2023 to May 2024. Medically compromised patients were excluded of the study. The implants were placed under local anesthesia in patients without surgical guided splints. All patients underwent diagnostic and post-surgical CBCT imaging within 6 months of surgery.
The outcome variables of the study are to test diagnostic CBCT accuracy in respect of bone hight, width at different level, and implant length and diameter variations after implant placement in Pakistani population. The participants' confidentiality was ensured by keeping the data secure. This study data was achieved with its confidentiality and approved by Institutional Review Board.

3. Statistical Analysis

To assess how accurately diagnostic CBCT imaging predicts changes in bone height, width, and implant diameter after surgery, we analyzed the data using various statistical methods. Descriptive statistics, specifically the mean and standard deviation, were calculated for each measurement to provide an overview of implant placement outcomes. The distribution of measurements was examined with the Shapiro-Wilk test to determine whether parametric or non-parametric tests were appropriate [14]. When comparing preoperative CBCT estimates with postoperative results, paired sample t-tests were employed for normally distributed data, while the Wilcoxon signed-rank test was used for data that did not meet normality criteria [15]. All analyses were conducted using GraphPad Prism version 8.0.2 for Windows (GraphPad Software, Boston, MA, USA), and a significance threshold of $P < 0.05$ was applied. Outcomes were presented with 95% confidence intervals to enhance the reliability of our findings on CBCT's diagnostic accuracy in this context.
For the demographic analysis, data were processed with IBM SPSS Statistics for Windows, Version 20 (IBM Corp., Armonk, NY, USA). Descriptive statistics summarized the study sample's characteristics, with frequencies and percentages used to illustrate data for categorical variables, such as gender, jaw type, and the number of implants. The Chi-square test was performed to evaluate variations within population subgroups.

4. Results

Patient demographics

The mean age of the patients in this study was 52.4 years, providing insight into the general age demographic of the sample (Table 1). A chi-square test was performed to assess whether the distribution across the age groups significantly deviates from a uniform distribution. The test statistic was 0.0 ($p=1.0$), indicating no significant difference across the age groups in this sample. The expected counts for each age group were same as actual, thus indicating that the observed and expected distributions align exactly, suggesting that the sample's age distribution is uniform across these age categories.

Table 1: Demographic data

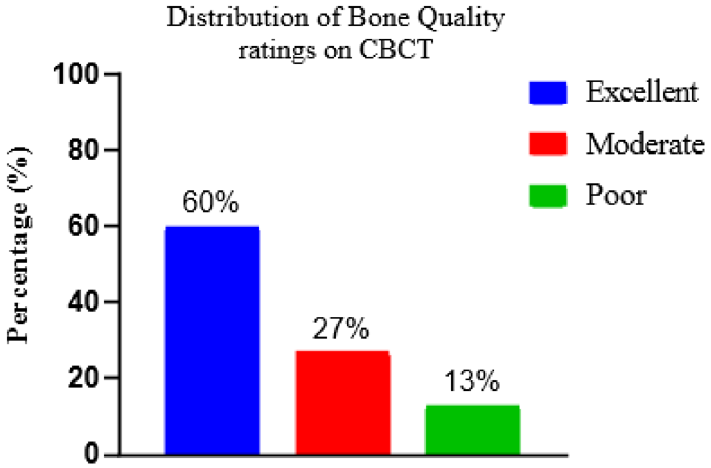
Category	**Value**
Mean Age (years)	52.4
Standard Deviation	7.57
Minimum Age	40
Maximum Age	60
Median Age	53
Interquartile Range	44.25 - 58
Age Group	
40-49 years	10
50-59 years	8
60+ years	4

Bone quality & Implants placement

A total of 136 implants were placed, with an average of approximately 6.18 implants per patient. Implants were distributed across both the maxilla (41.2%) and the mandible (58.8%). Bone quality was predominantly categorized as "Good" (60%), followed by "Satisfactory" (27%) and "Poor" (13%). There was a slight variation in bone quality between implant sites, with a higher incidence of "Poor" quality observed in the mandible. (Figure 1)

In terms of bone height assessed by CBCT, the majority of cases were rated as "Excellent" (70%), indicating generally favorable conditions for implant placement. Bone width assessments were more varied, with "Excellent" in 55% of cases, "Moderate" in 36%, and "Poor" in 9%, both assessed at mentioned points (Figure 1).

Figure 1



The chi-square test revealed a statistically significant association between implant site (maxilla vs. mandible) and bone quality (P < 0.05), suggesting that bone quality may differ between implant sites, potentially influencing implant placement decisions (Table 2). The data also shows a varied distribution of implant numbers per patient, with an average of approximately 6 implants (SD = 5.81), highlighting significant variation in implant needs across patients. Most patients had implants positioned toward the back of the mouth, as indicated by the median implant position of 34. This variability in both the number and location of implants underscores the importance of individualized treatment plans in dental implantology, taking into account each patient's unique anatomical needs and conditions for optimal implant placement

Table 2: Implant data

Parameter	Result
Total Implants	136
Average Implants per Patient	6
Implant Distribution	Maxilla: 41.2% (56), Mandible: 58.8% (80)
Bone Quality on CBCT	Good: 60%, Satisfactory: 27%, Poor: 13%
Bone Height on CBCT	Excellent: 70%, Moderate: 23%, Poor: 7%
Bone Width on CBCT	Excellent: 55%, Moderate: 36%, Poor: 9%
Implant Site vs. Bone Quality	Significant (P < 0.05)

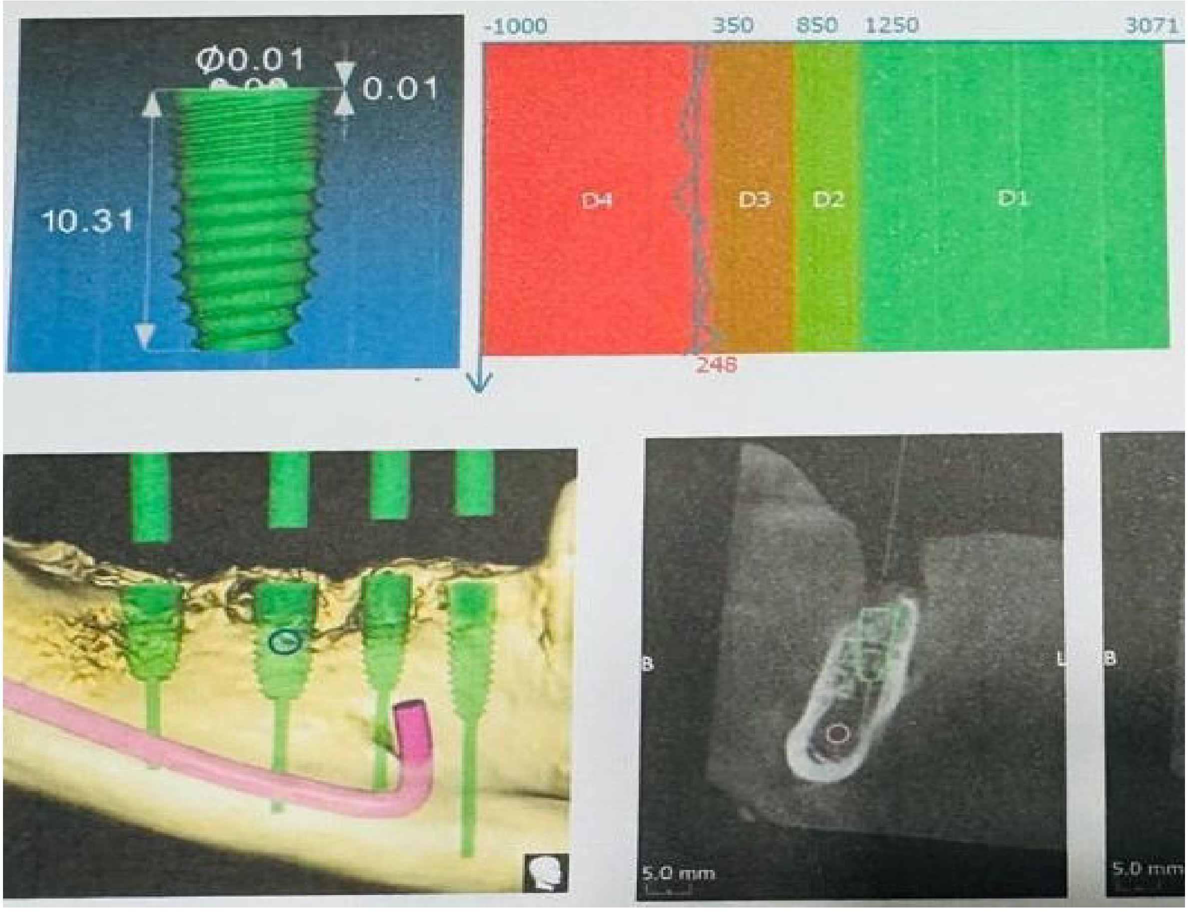


Figure 2

CBCT-Based Bone Density Assessment and Implant Placement Planning. This image illustrates the use of Cone Beam Computed Tomography (CBCT) for evaluating bone density and planning dental implant placement. The top right section provides a color-coded density map, categorizing bone quality into four density types: D1 (highest density, green) to D4 (lowest density, red), with corresponding pixel values to guide implant suitability.

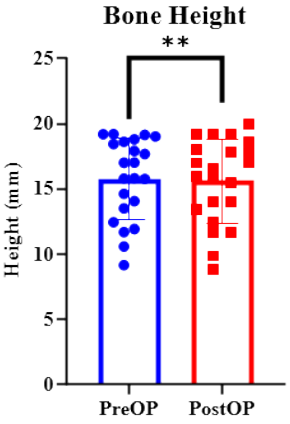
Bone quality & Implants placement

Table 3 presents a statistical analysis of CBCT measurements for bone height, coronal width, and apical width, comparing preoperative (Pre OP) and postoperative (Post OP) values, along with the calculated differences for each parameter. Descriptive statistics, normality testing, and paired comparisons were performed to assess changes across these dimensions.

Table No. 3 Comparison of CBCT Measurements: Bone Height, Coronal Width, and Apical Width Pre- and Post-Operatively

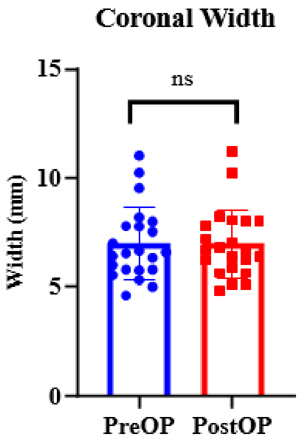
Test Statistic	CBCT Bone Height			CBCT Coronal Width			CBCT Apical Width		
	Pre OP	Post OP	Difference	Pre OP	Post OP	Difference	Pre OP	Post OP	Difference
Mean	15.78	15.58	0.19	6.98	6.97	0.02	9.77	9.68	0.08
S.D	3.12	3.22	0.37	1.67	1.58	0.72	2.84	2.83	0.94

Mean ± S.D	15.78 ± 3.12	15.58 ± 3.22	0.19 ± 0.37	6.98 ± 1.67	6.97 ± 1.58	0.02 ± 0.72	9.77 ± 2.84	9.68 ± 2.83	0.08 ± 0.94
Estimation for Normality (Shapiro-Wilk)									
P value	0.0381	0.1735	Non-Normally distributed data	0.0929	0.0514	Normally distributed data	0.0929	0.0514	Normally distributed data
Passed normality test (alpha=0.05)?	No	Yes		Yes	Yes		Yes	Yes	
P value summary	*	ns		ns	ns		ns	ns	
Test used based on data distribution	**Wilcoxon matched-pairs signed rank test**			**Paired t test**			**Paired t test**		
P value	0.0033			0.9232			0.9232		
P value summary	****			ns			ns		
Significantly different (P < 0.05)?	Yes			No			No		
One- or two-tailed P value?	Two-tailed			Two-tailed			Two-tailed		
Sum of positive, negative ranks	34.00 , -197.0			t=0.09758, df=21			t=0.09758, df=21		
Number of pairs	22			22			22		



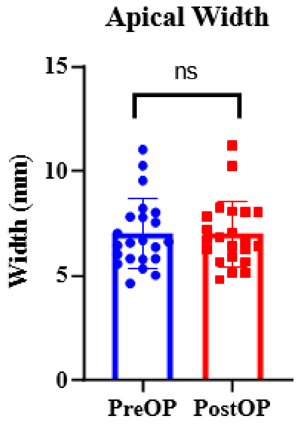
The data are peresented as Mean ± S.D. Wilcoxon matched-pairs signed rank test, p<0.01

A



The data are peresented as Mean ± S.D. Paired t test, ns

B



The data are peresented as Mean ± S.D.
Paired t test, ns

C

Figure 3

Figure 3 provides a statistical analysis of CBCT measurements for A) bone height, B) coronal width, and C) apical width, comparing pre-operative (Pre OP) and pos-toperative (Post OP) values with corresponding differences. The data are presented as mean ± standard deviation (SD) for each measurement parameter. Descriptive statistics, normality tests, and paired comparisons were performed to evaluate any significant changes across these dimensions

Bone Height

The average bone height before surgery was 15.78 mm (SD = 3.12), which decreased slightly after surgery to 15.58 mm (SD = 3.22), with a mean difference of 0.19 mm (SD = 0.37). Analysis with the Shapiro-Wilk test showed that the preoperative bone height data did not meet the criteria for a normal distribution (P = 0.0381), leading to the selection of the Wilcoxon matched-pairs signed rank test for further comparison. This test identified a statistically significant difference between pre- and postoperative bone height (P = 0.0033, two-tailed), suggesting a small yet notable reduction in bone height as a result of the procedure.

Coronal width

The mean preoperative coronal width was 6.98 mm (SD = 1.67), while the postoperative mean was 6.97 mm (SD = 1.58), with a minimal mean difference of 0.02 mm (SD = 0.72). Both pre- and postoperative coronal width data passed the normality test (P = 0.0929 and P = 0.0514, respectively), allowing for the use of a paired t-test. The paired t-test showed no statistically significant difference in coronal width between pre- and postoperative measurements (P = 0.9232), suggesting that coronal width remained consistent postoperatively.

Apical width

The mean preoperative apical width was 9.77 mm (SD = 2.84), with a postoperative mean of 9.68 mm (SD = 2.83), yielding a mean difference of 0.08 mm (SD = 0.94). Both pre- and postoperative apical width data showed normal distribution (P = 0.0929 and P = 0.0514, respectively), which allowed for the use of a paired t-test. The test revealed no statistically significant difference in apical width between pre- and postoperative measurements (P = 0.9232), indicating stability in apical width post-surgery. Similar results were found for coronal width, with a mean difference of 0.02 mm (SD = 0.72) and non-significant paired t-test results (P = 0.9232 for both), suggesting that CBCT imaging provides consistent and stable preoperative assessments of coronal and apical widths.

However, bone height showed a small but statistically significant postoperative reduction, with a mean difference of 0.19 mm (SD = 0.37), as indicated by the Wilcoxon matched-pairs signed rank test (P = 0.0033). This slight reduction in height could have clinical importance, as it suggests some level of bone resorption or remodeling after implant placement. Clinicians should consider this minor change when planning implant positioning, especially in cases with minimal available bone height.

Overall, these findings indicate that CBCT imaging is reliable for evaluating preoperative coronal and apical dimensions, which remain stable postoperatively. However, attention should be given to the minor height reduction observed, as it may impact implant stability and long-term success in clinical practice.

1.1. Comparison of CBCT and Actual Measurements of Implant Height and Diameter

Table 4 Statistical Comparison of CBCT and Actual Measurements of Implant Height and Diameter

Test Statistic	**Implant Height**			**Implant Width**		
	CBCT	**Actual**	**Difference**	**CBCT**	**Actual**	**Difference**
Mean	11.56	10.93	0.61	4.5	4.21	0.29
S.D	1.87	1.65	0.32	0.35	0.36	0.09
Mean ± S.D	11.56 ± 1.87	10.93 ± 1.65	0.61 ± 0.32	4.5 ± 0.35	4.21 ± 0.36	0.29 ± 0.09
Test used based on data distribution	Wilcoxon matched-pairs signed rank test			Wilcoxon matched-pairs signed rank test		
P value	<0.0001			<0.0001		
Exact or approximate P value?	Exact			Exact		
P value summary	****			****		
Significantly different (P < 0.05)?	Yes			Yes		
One- or two-tailed P value?	Two-tailed			Two-tailed		
Sum of positive, negative ranks	0.000, -253.0			0.000, -253.0		
Sum of signed ranks (W)	-253			-253		
Number of pairs	22			22		
Number of ties (ignored)	0			0		

The data in Table 4 and Figure 4 presents a comparative analysis of implant height and width measurements derived from CBCT imaging versus actual postoperative measurements. For implant height, the mean CBCT measurement was 11.56 mm (±1.87), compared to an actual postoperative mean of 10.93 mm (±1.65), yielding a statistically significant mean difference of 0.61 mm (±0.32) (P < 0.0001). Similarly, for implant width, the mean CBCT measurement was 4.5 mm (±0.35), while the actual width was 4.21 mm (±0.36), with a mean difference of 0.29 mm (±0.09), also statistically significant (P < 0.0001). These findings indicate a minor but consistent overestimation by CBCT for both height and width, with the statistical significance (P < 0.0001) highlighting the importance of considering these variations during clinical planning.

Overall, the results suggest that CBCT provides reasonably accurate approximations of implant height and diameter, though slight overestimations are evident. This overestimation, with mean differences of 0.61 mm for height and 0.29 mm for diameter, should be accounted for in surgical planning to enhance implant placement precision (Table 5).

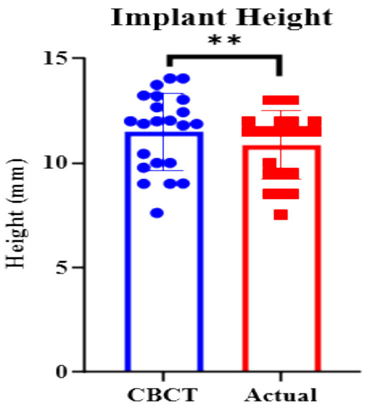
Table No. 5 Comparison of CBCT and Actual Measurements of Implant Height and Diameter

CBCT Implant Height	Actual Implant Height	Height Difference	CBCT Implant Diameter	Actual Implant Diameter	Diameter Difference
10	9.5	0.5	4.68	4.5	0.18
10.43	10	0.43	4.37	4	0.37
9.01	8.5	0.51	4.61	4.3	0.31
13.23	12	1.23	4.45	4	0.45
13.2	12	1.2	4.66	4.3	0.36
12.43	12	0.43	4.36	4	0.36
7.6	7.5	0.1	5.24	5	0.24
12.03	11.5	0.53	3.99	3.8	0.19
11.8	11.5	0.3	4.8	4.5	0.3
14.05	13	1.05	4.55	4.3	0.25
14.05	13	1.05	4.23	4	0.23
11.87	11.5	0.37	4.77	4.5	0.27
12	11.5	0.5	4.02	3.8	0.22
9	8.5	0.5	5.31	5	0.31
11.88	11.5	0.38	4.07	3.8	0.27
12	11.5	0.5	4.35	4	0.35
13.03	12	1.03	4.41	4.3	0.11
9	8.5	0.5	4.78	4.5	0.28
13.74	13	0.74	4.11	3.8	0.31
9.77	9.5	0.27	4.38	4	0.38
12.67	11.5	0.67	4.44	4	0.44
10	9.5	0.5	4.81	4.5	0.31

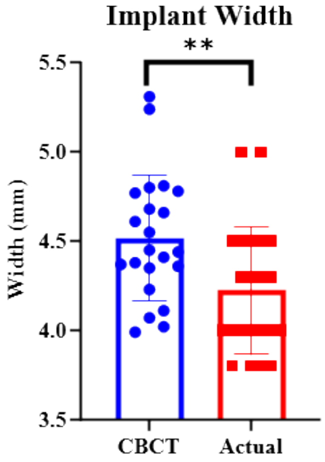
Mean	11.56	10.93	0.61	4.5	4.21	0.29
S.D	1.87	1.65	0.32	0.35	0.36	0.09
Mean ± S.D	11.56 ± 1.87	10.93 ± 1.65	0.61 ± 0.32	4.5 ± 0.35	4.21 ± 0.36	0.29 ± 0.09

Figure 4

Comparison of implant height and width (CBCT vs Actual)



The data are peresented as Mean ± S.D. Wilcoxon matched-pairs signed rank test, p<0.01



The data are peresented as Mean ± S.D. Wilcoxon matched-pairs signed rank test, p<0.01

Clinical implications

The findings from this study indicate that while CBCT provides reasonably accurate preoperative measurements for implant height and diameter, there are slight overestimations in both dimensions, with a mean difference of 0.61 mm for height and 0.29 mm for diameter. Clinically, these minor discrepancies have significant implications, particularly in surgical precision, implant stability, treatment planning, and the need for further research and calibration.

1. **Surgical Precision**: CBCT measurements' tendency to overestimate implant height and diameter suggests that clinicians should consider these variations during surgical planning, especially in cases with limited bone volume or proximity to critical anatomical structures, such as nerves or the sinus cavity [16] . Adjustments based on CBCT estimates may help prevent issues related to implant depth or width, enhancing placement precision and safety. For example, a study by Nickenig and Eitner (2007) supports the importance of careful interpretation of CBCT measurements to minimize risks during implant placement [15]. Making slight reductions to CBCT-predicted measurements in cases where bone

availability is restricted can help mitigate potential complications, such as nerve injury or sinus perforation, ensuring better surgical outcomes [17].

2. **Implant Stability and Osseointegration**: Accurate implant placement is essential for maximizing bone-to-implant contact, a key factor for successful osseointegration and long-term stability [18]. Overestimations in implant height or diameter could result in suboptimal implant positioning, potentially affecting the implant's load-bearing capacity and increasing the risk of mechanical complications. Studies have shown that even slight discrepancies in implant positioning may alter stress distribution around the implant, potentially compromising stability and integration with surrounding bone [19]. Clinicians can improve stability by adjusting CBCT measurements to more accurately represent actual bone dimensions, reducing the chance of excessive loading forces and enhancing implant longevity [20].
3. **Treatment Planning and Patient Expectations**: This study’s findings underscore the importance of transparent communication with patients regarding the minor variability in CBCT measurements and the clinical adjustments made during surgery. Discussing potential differences between CBCT-predicted and actual dimensions can help manage patient expectations and highlight the role of intraoperative modifications for optimal outcomes [21]. Patient-centered communication about the limitations of CBCT can foster trust and ensure patients understand the precision of their implant placement, as well as the care taken to avoid anatomical risks [22]. Managing expectations around implant positioning and stability can ultimately contribute to improved patient satisfaction and a clearer understanding of the surgical process.
4. **Further Research and Calibration**: The consistent overestimation observed in this study suggests the potential benefit of further research into CBCT calibration techniques or software modifications aimed at improving measurement accuracy. Other studies have noted similar findings, advocating for technology-driven enhancements or clinical calibration strategies to mitigate these discrepancies [23]. Research on calibration phantoms, for instance, could help standardize CBCT measurements, reducing the variability seen across different CBCT machines and software platforms [20] . Until such advancements are widely adopted, clinicians may consider experience-based calibration or using slightly conservative CBCT estimates when planning critical implant dimensions to improve surgical predictability.

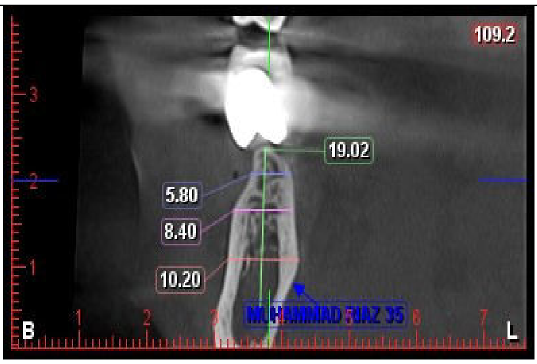
Overall, these findings highlight the value of CBCT in providing a detailed basis for implant planning, while also emphasizing the need for clinical judgment when interpreting CBCT measurements to ensure precise implant placement. As CBCT technology advances, integrating enhanced calibration protocols may further improve its accuracy, allowing for even greater reliability in dental implantology.

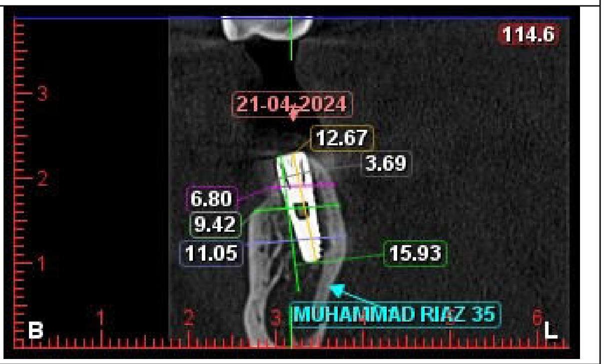
Figure 5

The implant images presented here illustrate the comparative alignment and dimensional differences between CBCT-predicted and actual postoperative implant placements.

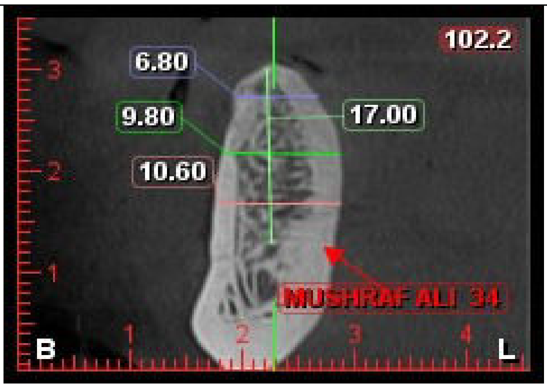
Pre-operative	Post-operative

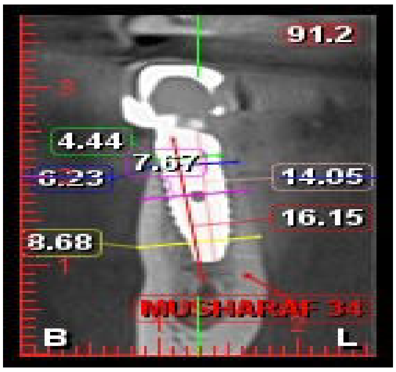
Patient No. 1



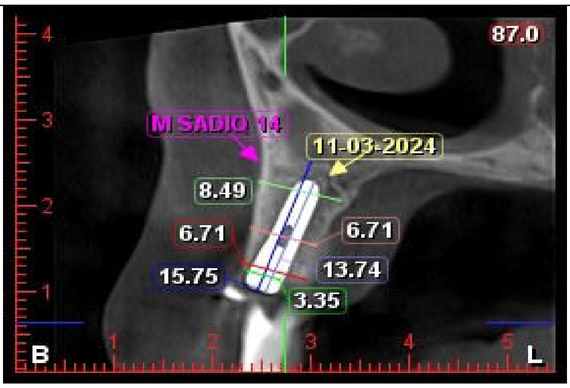


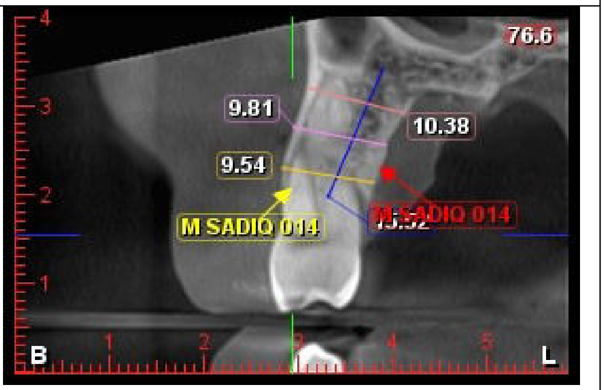
Patient No. 2

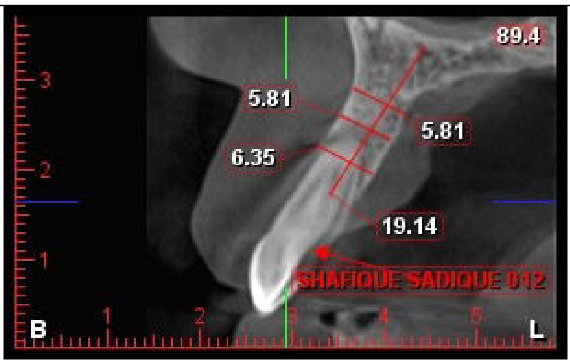




Patient No. 3





Patient No. 4	
	
Patient No. 5	

Discussion

Dental implants replace original missing teeth in humans, and they enforce stability and retention by osteointegration whereas, aesthetics and phonetics are mainly concerned with their prosthetic part. These abilities are best achieved by improving the process of evaluation and diagnosis system before surgical intervention and can be confirmed after surgery. For last two decay, the CBCT imaging implementation have produced revolutionary changes in maxillofacial surgery, especially implantology and the evaluation of the density quality of recipient bone is one of its additional properties, which will alleviate the adverse systemic and local effects that contribute to improper osseointegration in dental implants [7, 11]. The success of implants, their stability, painless healing and positioning may grantee only with best clinical examination and diagnostic techniques [8].

In this research article, the prosthetic part was delivered with the torque of abutment 35N for mandibular and 25N for the maxillary implants after osseointigration period. Follow up for after the implant placement accuracy has been assessed by post operative CBCT scan within six months of implant placement [24].

In our research, the coronal plane of three-dimensional imaging system is used for depiction of the required parameters and variables whereas, other planes were not suitable recommended plane to access the required variables [25]. We have noticed that there were significant dimensional changes observed in bone height measurements (P = 0.0033, two-tailed), indicating a small but meaningful change in bone height following surgery. In coronal width using a paired t-test, no statistically significant difference pre- and postoperative measurements (P = 0.9232) was noted likewise in apical width (P = 0.9232) indicating stability after surgery. In another research, Voxel size images show larger size (0.40mm) which effect the quality of the patient's clinical planning [8]. Rios et al., (2017) have shown increased CBCT imaging size which highlights its diverse applications for dental implant therapy and should be used selectively as an adjunct to two-dimensional dental imaging [26]. Although in our case there are differences in CBCT estimated parameters and definite ones measured later, however, postoperative cone beam computed tomographs has shown significantly increased accuracy and efficiency of diagnostic and treatment capabilities and was assumed unparalleled diagnostic approach. The potential benefits for accurate assessment in diagnosis of pathologies, identification of landmarks and neurovascular structures in pre-surgical treatment planning was undisputed while taking due consideration of benefits, radiation risk and cost [12].

When the implant height and width post CBCT images measured are compared to actual implant placed measurements, they are statistically significant ($P < 0.0001$) in both, indicating a slight overestimation in both height and width by CBCT, underscoring the need to account for these variations in clinical practice. The study's findings suggest that CBCT imaging is a valuable tool for enhanced planning of immediate implant placement procedures, particularly for maxillary molars. By using CBCT, clinicians were able to select implants with wider diameters rather than just focusing on length, helping to achieve primary stability. This method offers greater flexibility in implant choice, supporting more stable placements from the start [27].

Regarding bone density, CBCT also proves helpful in assessing the bone quality, which is crucial for successful implant placement. In this study, a chi-square test identified a statistically significant association between implant site (maxilla vs. mandible) and bone quality ($P < 0.05$), indicating that bone density may vary depending on the implant site. Clinically, the mandibular bone generally exhibited better density than the maxilla. High-density D1 bone was mostly observed in the mandible, while D2 and D3 densities, which are still favorable for implant placement, were found in both jaws. D4, representing poor quality bone, was mostly seen in older female patients. Another study by Gaur et al. (2022) compared bone density measurements using Hounsfield units (HU) on CT scans and noted that CBCT grayscale values may not be as reliable as CT HU for accurately gauging bone density. The study concluded that CBCT measurements need further standardization before clinical application [28].

It's also important to acknowledge some limitations of CBCT. Although our study did not encounter significant artifacts, existing literature indicates that CBCT scans of patients with existing restorations and implants can sometimes show scatter and beam-hardening artifacts, which may reduce image quality. Nevertheless, CBCT has transformed implant dentistry, driven by advancements in scanning equipment and viewing software that allow for highly detailed treatment planning [29]. Although virtual implant planning was beyond the scope of this study, combining CBCT with CAD/CAM technology enables clinicians to visualize the final result before starting treatment, allowing for precise planning and placement of implants to replace missing teeth, potentially minimizing both expected and unforeseen complications. This process ultimately benefits both clinicians and patients by enhancing treatment predictability [30]. Notably, there were no cases of implant infection in our study group, though some cases did show coronal bone loss on follow-up. A similar study reported bone loss around implants at six and twelve-month follow-ups using CBCT imaging [31]. Overall, CBCT imaging can be recommended as a critical tool for planning immediate implant placements, as it provides essential details for achieving primary stability and function. Diagnostic imaging remains a cornerstone of dental implant therapy, playing a vital role in preoperative planning, as well as in intraoperative and postoperative evaluations, especially when compared to panoramic radiography.

Conclusions

CBCT has significantly improved the accuracy and efficiency of diagnostic and treatment abilities by offering an exceptional diagnostic approach. It is an advance diagnostic available tool which has reasonable potential to impart current standards of care in oro-facial dentistry especially in implant dentistry. Dental implants are commonly used for the replacement of missing teeth and the assessment of bone quality and quantity to the implant site is important for the success and stability of these implants. The gold standard to achieve these properties is, to use of CBCT imaging which is indispensable in emerging implant dentistry. The volumetric data acquired by CBCT in our study simulates the ideal implant placement and prosthetic considerations. In the study, the bone is measured in height and width at different levels, along with implant diameter on CBCT image. Though the results are compromising but encouraging and may include CBCT operational depiction drawbacks or exposure angulation issues. It is wisely contributed here to justify our results by further research.

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