Cross-Sectional Study

PREVALENCE OF BONE LOSS AROUND DENTAL IMPLANTS MEASURED USING CONE BEAM COMPUTED TOMOGRAPHY: A CROSS-SECTIONAL STUDY

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ABSTRACT

This research examines the extent and phases of crestal and apical bone resorption in implant-supported restorations, as assessed with CBCT, and analyzes the role of age and gender as risk factors for crestal and apical bone loss around dental implants. CBCT study involving 753 cross-sectional scans showed a high proportion of early-stage bone resorption in Class I (77.3%), apical bone loss, and 86.7% of Stage I crestal bone loss. Years in function showed a positive correlation with crestal bone loss. This might mean that patients with longer-standing implants are more likely to have their surrounding bones degraded. The levels of bone loss did not vary much between males and females. These findings align with prior studies by underscoring CBCT's diagnostic accuracy and emphasizing that its use may facilitate appropriate treatment initiation. The findings particularly highlight the importance of integrating CBCT scans for implant assessment at intermediate time intervals, especially for the senior population, to avoid further depreciation of osseous tissues. The findings of this investigation endorse the inclusion of CBCT in standard peri-implant evaluations as a valuable resource for optimizing patient and implant prognosis. To develop more efficient solutions for CBCT-guided monitoring and management of affected teeth, future studies should also explore other risks, such as systemic health conditions.

Key words: Bone loss, Dental implants, Cone beam computed tomography, Risk factors.

Introduction

Peri-implant bone resorption is considered to be a critical determinant of both the survival and success of implant therapy. Some factors that may lead to bone loss around the implant include peri-implantitis, poor plaque control, occlusal stress, and certain diseases such as diabetes and osteoporosis [1]. Bone loss is critical to detect as early as possible and can lead to severe complications; therefore, early detection is recommended. Another technological development is cone beam computed tomography (CBCT), which is used to diagnose bone loss. It is more accurate in this imaging because it provides a three-dimensional image and offers a finer view of bone structures than conventional two-dimensional radiography. Knowledge of the incidence of bone loss will facilitate better patient management and the development of early diagnosis approaches [1].

Crestal and apical bone loss is a major concern with dental implants, as it is one of the most significant factors determining the success rate of placed implants. Implant failure rate, associated with a 20%-25% loss of bone around the implant, is likely to occur within the first five years of implant placement. The majority of them are possible due to peri-implantitis, an inflammatory disease that affects the implant [2]. Oral risk factors comprise smoking, poor oral hygiene, and non-communicable diseases such as diabetes [3]. CBCT has been described as the most effective method for evaluating bone loss because it produces a three-dimensional image. The advantages of CBCT over the radiographic technique in the visualization of the disease process highlighted that the ability of CBCT to pick up early bone resorption that is otherwise unclear on conventional radiographs was indeed an added advantage since it enables early diagnosis of the pathology and its timely management to prevent implant failure [4].

A cross-sectional study by Vervaeke *et al*. (2016) [5] included 300 patients and used CBCT to assess bone resorption around dental implants. The outcomes showed that approximately 30% of the implants were associated with bone density loss exceeding 2 mm in the vertical dimension. The highest rates were established among patients with unsatisfactory oral hygiene and diseases of the body, such as diabetes. During the study, the authors established that frequent CBCT scanning could detect early bone loss and improve dental implant outcomes. Several factors have been found to affect the rate of peri-implant bone loss, especially systemic conditions such as diabetes.

Oh *et al*. (2002) [6] analyzed worldwide data on peri-implant bone loss and observed that the incidence ranged from 15% to 35%, depending on patient age, the surgical procedures used for implant placement, and the various follow-up intervals. According to the study, CBCT should be used regularly for follow-up examinations to detect early signs of bone loss and to initiate preventive measures, including dental health and systemic disease control [7].

In another study, Hu *et al*. (2019) [7] analyzed the effects of early intervention on peri-implant bone loss. The use of CBCT was also helpful in early identification of bone loss, which, in turn, allowed the authors to treat the site with surgical debridement and guided bone regeneration before the extent of bone loss became so severe as to compromise the stability of the implants. This supports the use of CBCT, especially for high-risk patients [8].

Marginal bone resorption is one of the factors that should be considered as an indicator of dental implants' stability and success. The screening for bone loss is useful because conditions such as peri-implantitis, occlusal overload, poor oral hygiene, and certain systemic diseases can cause implant failure [9, 10]. CBCT is essential for assessing peri-implant bone loss, primarily because of its high image resolution, which provides the dentist with a multi-view perspective of peri-implant bone tissue.

Stability research has also highlighted the importance of both bone quantity and quality, with cortical bone thickness and bone mineral density being primary determinants of success. In a recent study by Rues *et al*. (2019) [2], the authors showed that implant stability increased with cortical thickness when cortical thickness was greater than the implant diameter. Also, Hu *et al*. (2019) [7] reported on the use of CBCT to assess early changes in peri-implant bone and identify possible benefits for enhancing clinical outcomes through early diagnosis and intervention.

This investigation seeks to determine the frequency and grade of crestal and apical bone loss using CBCT and evaluate for any predisposing factors. Thus, it aims to advance the current literature on early detection by providing a better understanding of its effects on implant stability and durability, thereby buttressing CBCT's role as a diagnostic tool in implant Dentistry.

Hypothesis
The prevalence of crestal and apical bone loss around the implants is low.

Study aim
To measure the occurrence of crestal and apical bone loss related to dental implants utilizing CBCT scans.

Study objectives
To assess the radiographic stages of implant disease and evaluate radiographically noticeable predisposing factors.

Materials and Methods

Study sample
Sample size was calculated using the formula described by Aljasser *et al*. (2021) [11].

$$n = (z)2\,p\,(1 - p)\,/\,d2 * \quad (1)$$

$$n = (1.96)2 * 23.76 * 74.26/3 * 3 \quad (2)$$

$$n = 753 \text{ CBCT scans} \quad (3)$$

These scans were requested from the REU radiology department after the ethical approval was received.

Inclusion criteria
- CBCT scans of implants placed from 2015 to 2023.
- Scans with a field of view of 8x8 up to 10x10 cm.
- Scans of patients aged 18 years or older.
- Patients with more than one CBCT scan in their file.

Exclusion criteria
- Scans older than 2015.
- Scans other than the specified field of view.
- Scans of patients less than 18 years of age.
- Scans that were of low quality.
- Scans with artifacts.

Radiographic examination
Scans were examined by two examiners to ensure intra-examiner reliability, and the interclass correlation coefficient of 0.92 was achieved. Data on the patient's gender and age were recorded.

Crestal bone loss: CBL was categorized according to the following criteria:
- Stage I: less than 25% of the length of the implant
- Stage II: 25-50% of the length of the implant
- Stage III: more than 50% of the length of the implant

These stages were taken from the classification used to measure peri-implantitis by Froum and Rosen (2012) [12].

Apical bone loss**:** APL was categorized according to the following criteria:
- Class I: where the radiographic bone loss is recorded to be less than 25% of the length of the implant.
- Class II: where the radiographic bone loss is recorded to be 25%-50% of the length of the implant.
- Class III: where the radiographic bone loss is recorded to be more than 50% of the length of the implant.

These measurements are taken from the classification presented by Shah *et al*. (2016) [13].

Data analysis
Initially, the data were collected in an Excel sheet; later, they were transferred to Statistical Package for the Social Sciences (IBM SPSS Statistics for Windows) version 21. Descriptive as well as inferential statistics were performed and presented in tables and graphs. A chi-square test was conducted to assess the relationship between crestal and apical bone loss and patient demographics, with localized predisposing factors (such as implant position and angulation) visible on the radiograph.

Results and Discussion

Table 1 displays participants' gender, age, and their relationship with crestal or apical bone loss stages. The study's target population comprised 753 patients; 57.8% were male, and 42.2% were female, with an average age of 39.6 years (SD = 7.1). Most of the implants (86.7%) had crestal bone loss assessed at Stage I, while 10.4% at Stage II, and 2.9% at Stage III. As observed in other parameters, Class I apical bone loss was also more widespread (77.3%), while Class II was found in 20.3% of patients, and Class III affected only a tiny fraction (2.3%). In this distribution, one can argue that bone loss is being identified early enough and thus well detected.

Table 1. Descriptive analysis of study participants and bone loss

Variables	Descriptive analysis
Gender	Males: 435 (57.8%) Females: 318 (42.2%)
Age	Mean: 39.606 (SD 7.118)
Crestal bone loss	Stage 1: 653 (86.7%) Stage 2: 78 (10.4%) Stage 3: 22 (2.9%)
Apical bone loss	Class I: 582 (77.3%) Class II: 153 (20.3%) Class III: 18 (2.3%)

Thus, **Figure 1** presents a graphical view of the gender distribution, where male respondents are slightly more numerous than female respondents.

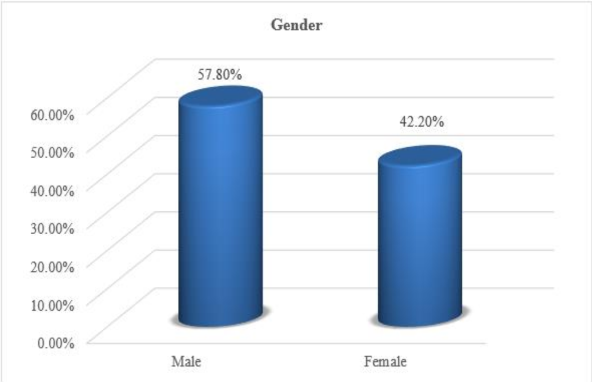

Figure 1. Gender distribution of study participants

In the same context, **Figure 2** presents the distribution of crestal bone loss by stage. The dominant Stage I cases suggest that regular CBCT use leads to timely detection, potentially reducing progression to later stages.

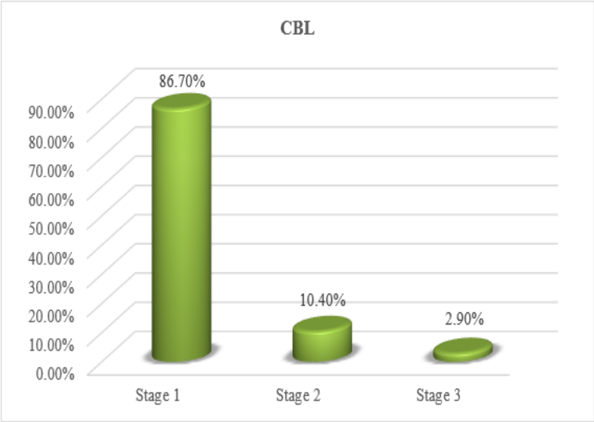

Figure 2. Crestal bone loss stages among study participants

Figure 3 shows the distribution of apical bone loss (ABL) among participants, classified into three categories: Class I, II, and III. The majority (77.3%) are in Class I, indicating early apical bone loss; thus, CBCT screening can help detect it. Class II comprises 20.3% of participants with moderate bone loss, and only 2.3% are in Class III, the most severe class. In particular, the preponderance of Class I patients underscores the need for early diagnosis, given the high potential for further progression.

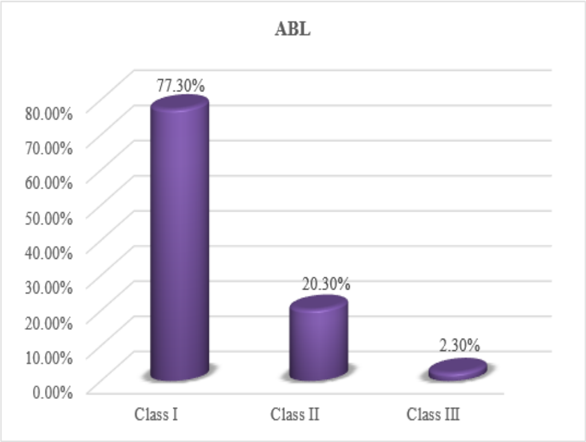

Figure 3. Apical bone loss classes among study participants

Tables 2 and 3 present the chi-square test results, which reveal no significant differences in crestal and apical bone loss by gender.

Table 2. Chi-square test to compare the apical bone loss among genders

Gender/APL	Stage 1	Stage 2	Stage 3	P-value
Male	78%	19%	3%	.762
Female	77%	22%	2%	

Table 3. Chi-square test to compare the crestal bone loss among genders

Gender/CPL	Class I	Class II	Class III	P-value
Male	86%	11%	3%	.937
Female	87%	10%	3%	

Table 4 shows a positive correlation between age and crestal bone loss, suggesting an age-related increase in bone degradation around implants.

Table 4. Spearman correlation test to correlate age with bone loss types

	APL	CPL
Correlation with age	.046	.109
P-value	.364	.032*

The results of this study indicate that early bone loss around implants (Stage I crestal and Class I apical) is common, and, indeed, age is a significant predictor of crestal bone loss. These findings raise awareness of the need for early screening and demonstrate that CBCT helps diagnose early changes that are not evident in later stages of bone degeneration. As highlighted by earlier work, CBCT can help monitor implants, as supported by the results of this study. Berglundh *et al*. (2019) recognized that CBCT can reveal three-dimensional morphological changes and may detect small amounts of peri-implant bone loss at the earliest stages, before implant stability is compromised [9]. According to the present study, early-stage bone loss was highly prevalent, corroborating Berglundh's findings and supporting CBCT as a valuable diagnostic tool for maintaining peri-implant health.

Primary implant stability is closely related to bone quality and quantity. It has attracted significant attention from researchers in recent years, with lateral cortical bone thickness and BMD identified as key factors. Rues *et al*. noted that superior primary stability increases with greater cortical bone thickness, which is critical for implant integration and sustainability. This study did not quantify cortical thickness per se; however, because the bone loss process was mostly in the earlier stages, it may be that, even if cortical thickness is suboptimal, CBCT's sensitivity ensures it can detect such scenarios before advanced bone loss has occurred. An aspect of CBCT use that aligns with Pommer *et al*. (2019) is its efficiency in diagnosing early-stage bone resorption [14].

CBCT is indispensable for diagnosing early periprosthetic conditions and preventing further progression of peri-implant bone loss in high-risk patients, as Pommer *et al*. (2019) implied [14]. According to Pommer *et al*. (2019), the present assessments corroborate his claim by highlighting a predominance of Stage I and Class I bone loss [14], which further suggests that CBCT should be implemented into regular follow-ups. Age was found to influence crestal bone loss; older patients had a higher rate of bone resorption around the implants. Hu *et al*. (2019) also determined that age is a risk factor for peri-implant bone loss because, as patients age, bone density is expected to decline, thereby causing implant instability [7]. As noted in the current study's results on the relationship between age and crestal bone loss, Hu *et al*. (2019) also observed a need for routine CBCT examinations in aged individuals [7]. This correlation suggests that older patients are more vulnerable to gradual bone density loss, so the identification of the condition is essential in this population. Periodic CBCT scans could therefore enable early detection and treatment, thereby eliminating severe resorption and minimising implant failure in older patients. Further, as a result of the study, the clinician should establish rigorous screening protocols for elderly patients, as they have much to gain from CBCT's preventive role in early detection of mouth cancer.

There was no substantial difference in peri-implant bone loss by gender in this study. However, the present study's findings regarding gender are consistent with earlier research by Alani *et al*. (2019) [10]. According to Alani *et al*. (2019) [10], there were only slight differences in the rate of peri-implant bone loss by gender; thus, they concluded that gender may not be a significant factor influencing peri-implant bone loss. The absence of gender differences in crestal and apical bone loss in this study also reinforces the idea that peri-implant health evaluations and follow-ups can be extended across genders. These results are valuable for today's clinical practice, as they suggest that both male and female patients can benefit from CBCT's truly diagnostic capabilities. Sex-defining osteopenia confirmation strengthens the range of indications for using CBCT and proves the advisability of considering it as one of the most suitable methods for diagnosing various populations.

Compared to traditional radiographic approaches, CBCT offers advantages in terms of visualization depth and accuracy, which are inherently required for the recognition of various stages of alveolar bone loss. Zhang *et al*. (2020), for instance, noted the shortcomings of traditional two-dimensional radiography, especially in evaluating the degree of bone loss around implants [15]. Zhang *et al*. (2020) also stated that, owing to its volumetric data [15], CBCT offers greater viewing options than traditional imaging and helps identify signs of bone resorption that can be easily overlooked. The present study's results, showing increased prevalence of early-stage bone loss, support this advantage, as CBCT's capacity to detect minor alterations in bone morphology enables clinicians to intervene before the condition progresses to a later stage. These findings are pertinent in the clinical domain, particularly for applications that support the assembly of dental implant patients' treatment plans and aftercare regimens.

However, the following limitations of this study must be noted: the cross-sectional design limits the ability to track the progression of bone mass loss over time, as the collected data provide only a single point estimate of each patient's bone health. A more prospective investigation is required to assess alterations in bone levels around implants; such an approach would provide further understanding of CBCT's efficacy in minimizing severe peri-implant bone loss in the long term. Furthermore, this study did not control for other possibly confounding factors, including internal etiologies of diseases, smoking, or the taking of drugs, which can affect the status of peri-implant bone. Subsequent studies should take these parameters into account to provide a broader perspective on the implant risk analysis associated with peri-implant bone loss and to improve preventive measures [15].

Future research should also find out the effects of lifestyle and systemic diseases like diabetes and smoking on peri-implant bone loss. Diabetes and smoking have also been well-known factors affecting the osteointegration in the bones, which can be fatal to the implants and are also known to accelerate bone resorption [16]. If these factors can be correlated with bone loss stages identified by CBCT imaging, understanding them can help clinicians develop better management strategies for patients with such disorders. In addition, data on systemic medications used in patient management, particularly bisphosphonates for osteoporosis, could help clarify their influence on bone metabolism around implants. As bisphosphonates affect bone remodeling, evaluating their effects on the stages of peri-implant bone loss could help develop individualized treatment regimens for patients receiving bisphosphonates.

Conclusion

This study has therefore used CBCT to identify early-stage peri-implant bone loss, demonstrating its promise in extending implant lifespan through early intervention. These findings provide evidence that, because of CBCT's superior imaging, it can detect mild changes that are not distinguishable on radiography; therefore, the high frequency of stage I crestal and Class I apical bone loss is evident in this study. This research confirms the regular use of CBCT in implant evaluations to identify high-risk groups and prevent progression to later stages of bone loss that could make implants less stable. A statistically significant relationship was found between age and the cross-sectional thickness of crestal bone, so elderly patients may require more judicious follow-up due to a greater propensity to lose crestal bone around implants. This supports earlier findings on the role of CBCT in diagnosing and maintaining implant health in the elderly population. There were no gender differences in tomographic dental bone loss measurement coefficients that corroborated CBCT's versatility among patients of all backgrounds. Although this research aims to enrich global understanding of the topic under study, it faces several limitations, including a cross-sectional research design and the absence of systematic health data. Long-term investigations could reveal changes in bone density over time, and subsequent research could expand the list of potential risk factors, including smoking, diabetes, and medications, to determine whether more individualized supervision measures are required. Therefore, CBCT is a promising diagnostic technique that significantly enhances the diagnostic capabilities of standard clinical practice in dental implantology. CBCT enables effective detection of conditions at their initial stages, thus allowing preservation of peri-implant health and leaving little room for surgical interventions.

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