Research Article

CBCT-Based Radiographic Assessment of Buccal Bone Dehiscence and Fenestration Around Dental Implants in Adolescents

Sumit Bhatt[1] , Richa Wadhawan[2] , Nidhi Arya[3] , Uma Devi Sayyaparaju[4] , Gurinder Kaur Thind[5] , Manish Anand[6]

[1]Assistant Professor & PhD Scholar, Department of Oral & Maxillofacial Surgery, Rajasthan Dental College & Hospital, Nirwan University, Jaipur, Rajasthan, India , sumittbhatt22@gmail.com
[2]Professor & Head, Faculty of Dental Sciences, PDM University, Bahadurgarh, Haryana, India , wadhawanricha1@gmail.com
[3]Reader Department of Oral & Maxillofacial Pathology and Oral Microbiology, Seema Dental College & Hospital, Rishikesh, Uttarakhand, India , drnidhiarya19@gmail.com
[4]Senior Lecturer, Department of Prosthodontics and Crown & Bridge, St. Joseph Dental College, Duggirala, Eluru, Andhra Pradesh, India , umaprostho@gmail.com
[5]Post Graduate Student, Department of Prosthodontics and Crown & Bridge, Desh Bhagat Dental College & Hospital, Mandi Gobindgarh, Punjab, India , gkaurkamboj@gmail.com
[6]Resident, Department of Oral & Maxillofacial Surgery, Henry M Goldman School of Dental Sciences, Boston University, Boston, Massachusetts, United States of America , manishanand028@gmail.com
Corresponding author: Sumit Bhatt, sumittbhatt22@gmail.com

Abstract

Background:
The integrity and thickness of the buccal cortical plate are important considerations in dental implant treatment. Defects such as buccal bone dehiscence and fenestration may compromise peri-implant hard-tissue support. Cone-beam computed tomography (CBCT) enables three-dimensional (3D) assessment of these anatomical changes.
Aim:
The present study aimed to evaluate the prevalence and characteristics of buccal bone dehiscence and fenestration around dental implants using CBCT and to compare the occurrence of these defects between maxillary and mandibular implant sites.
Materials and Methods:
A total of 100 implant sites were assessed using CBCT images. The sites were evaluated for the presence or absence of buccal bone dehiscence and fenestration. Buccal bone thickness and the dimensions of identified defects were measured using multiplanar CBCT sections. The distribution of defects between maxillary and mandibular sites was also analyzed. Appropriate statistical tests were applied to determine associations and differences between the evaluated parameters.
Results:
Buccal bone dehiscence was identified more frequently in mandibular implant sites than in maxillary sites. Dehiscence was present in 15 of 40 mandibular sites (37.5%) compared with 9 of 60 maxillary sites (15.0%), and the difference was statistically significant. Sites with buccal bone dehiscence demonstrated reduced buccal bone thickness compared with sites without dehiscence. Buccal bone fenestrations were also identified and their dimensions were recorded using CBCT measurements.
Conclusion:
CBCT provides valuable 3D information for identifying and measuring buccal cortical bone defects around dental implants. The greater frequency of dehiscence in mandibular sites and its association with reduced buccal bone thickness emphasize the importance of assessing the facial cortical plate during implant evaluation and treatment planning.

Keywords: Adolescents, Buccal bone, CBCT, Cortical bone thickness, Dental implants, Dehiscence, Dental implants, Fenestration

Introduction

Dental implants have become an important option for replacing missing teeth and can provide favorable functional and esthetic outcomes when appropriate treatment planning is undertaken. The long-term success of implant therapy is influenced by adequate peri-implant hard- and soft-tissue support, with the facial cortical plate playing an important role in maintaining bone volume and tissue architecture around the implant [1].
Adolescents require particular consideration when implant-supported rehabilitation is planned because craniofacial and alveolar development may still be ongoing. Unlike natural teeth, osseointegrated implants are ankylosed to the surrounding bone and do not adapt to growth-related changes or the eruption and positional movement of adjacent teeth. Implant placement before completion of growth may therefore lead to infraocclusion, positional discrepancies, and subsequent esthetic or functional complications. Accordingly, comprehensive evaluation of skeletal maturity, alveolar development, and the quantity and integrity of the facial cortical bone is essential before implant treatment is considered in adolescent patients [2].
The morphology and dimensions of the alveolar ridge can also influence the amount of bone available around an implant. A narrow facial cortical plate or inadequate buccolingual ridge width may increase the possibility of incomplete facial bone coverage. Buccal bone dehiscence describes loss of the facial cortical plate extending from the marginal region along the implant surface, whereas fenestration represents a localized window of bone loss

with preservation of the marginal cortical bone. These defects may be influenced by implant diameter, implant position and angulation, ridge morphology, and the relationship between the implant and the facial cortical boundary [3, 4].

Identification of these osseous defects is important because insufficient facial bone coverage may affect the stability and dimensional maintenance of peri-implant tissues. Conventional periapical and panoramic radiographs provide useful information regarding implant position and crestal bone levels but have inherent limitations in evaluating the buccal and lingual surfaces because of their two-dimensional (2D) representation [5].

Cone beam computed tomography (CBCT) has enabled three-dimensional (3D) assessment of implant sites and surrounding osseous anatomy. It allows evaluation of buccolingual ridge dimensions, cortical bone thickness, bone height, implant position, and the relationship between implants and adjacent anatomical structures. This additional information can facilitate detection and characterization of facial cortical defects that may not be clearly demonstrated on conventional radiographs [6].

The diagnostic value of CBCT for peri-implant bone assessment has been investigated in relation to the detection and measurement of facial bone defects. 3D imaging may provide more detailed visualization of cortical discontinuities and the extent of bone coverage; however, image quality, voxel dimensions, acquisition parameters, and artifacts produced by metallic implant components can influence the accuracy of radiographic interpretation [7].

Evaluation of the facial bone envelope is particularly relevant in adolescent patients because implant placement must be considered in the context of continuing dentoalveolar changes. A localized cortical defect identified on CBCT may provide information about the existing peri-implant bone condition and may assist in evaluating the adequacy of facial bone coverage during treatment planning [8].

Despite the increasing application of 3D imaging in implant dentistry, studies specifically addressing the occurrence and radiographic characteristics of buccal bone dehiscence and fenestration around dental implants in adolescents remain relatively limited. Most available evidence has been generated from adult populations, and the influence of younger age and developing alveolar anatomy on these defects has not been adequately characterized. Further investigation is therefore warranted to establish the distribution of these defects and their relationship with relevant implant and anatomical characteristics [9].

Therefore, the present study was designed to evaluate buccal bone dehiscence and fenestration around dental implants in adolescents using CBCT. The study aims to determine the prevalence and distribution of these osseous defects and to assess their association with relevant implant-related and anatomical parameters, thereby contributing to improved radiographic evaluation and individualized implant treatment planning in adolescent patients.

Materials and Methods

Study Design and Sample

A cross-sectional observational study was conducted at a single tertiary care centre from October to December 2025 to evaluate buccal cortical bone defects around dental implants using CBCT. A total of 100 adolescent participants, aged 10–19 years, were included in the study. Each participant contributed a single dental implant site, resulting in a total of 100 implant sites for evaluation. Of these, 60 implant sites were located in the maxilla and 40 in the mandible.

Inclusion Criteria

- Adolescent patients aged 10–19 years who had dental implants placed in the maxillary or mandibular arch
- Implant sites with adequate-quality CBCT images suitable for evaluation of the buccal cortical plate
- Sites containing a clinically or radiographically identifiable dental implant
- Implant sites located in either the maxilla or mandible
- CBCT scans showing the entire implant and the surrounding buccal cortical bone clearly
- Images allowing assessment of buccal bone thickness, dehiscence, and fenestration
- Sites with sufficient image quality to permit reliable linear measurements of buccal cortical bone thickness and defect dimensions

Exclusion Criteria

- CBCT scans with poor image quality or excessive motion artifacts
- Implant sites in which the buccal cortical plate could not be clearly visualized
- Images with severe metallic artifacts obscuring the implant–bone interface
- Sites with incomplete visualization of the implant or surrounding alveolar bone
- Patients with a history of major trauma, extensive bone pathology, or surgical alteration affecting the implant region
- Sites with extensive peri-implant bone destruction that prevented reliable assessment of the buccal cortical plate
- Duplicate or repeated CBCT examinations of the same implant site
- Images in which accurate measurement of buccal bone thickness or defect dimensions was not possible

CBCT Acquisition Protocol

CBCT examinations were performed using the Carestream CS 9300 CBCT unit (Carestream Dental, Rochester, NY, USA). The field of view (FOV) was 10 × 10 cm, with a voxel size of 0.18 mm. The exposure parameters were set at 90 kV, 10 mA, and 8 seconds, according to the imaging protocol used for the selected patients.

Patients were positioned according to the manufacturer's recommended protocol, with the head stabilized and the occlusal plane oriented parallel to the horizontal reference plane. Images were acquired with the patient in a seated position, and instructions were provided to minimize movement during scanning.

CBCT Image Assessment

The selected implant sites were evaluated using multiplanar reconstructed CBCT images. The buccal cortical plate adjacent to each implant was examined for the presence of buccal bone dehiscence and fenestration. Buccal bone dehiscence was defined as a loss or absence of the buccal cortical plate extending from the crestal region along the implant surface. Buccal bone fenestration was defined as a localized area of cortical bone deficiency involving the implant surface, with preservation of the surrounding crestal and apical cortical bone.

Image Reconstruction and Measurement

The acquired CBCT datasets were analyzed using Carestream CS 3D Imaging software, version 3.10. Multiplanar reconstructed images, including axial, sagittal, and coronal sections, were used for evaluation. The long axis of each implant was identified and used as the principal reference axis for standardized assessment. Buccal bone thickness was measured on cross-sectional images at predefined levels along the implant. Measurements were obtained from the outer surface of the implant to the external surface of the buccal cortical plate. All measurements were recorded in millimetres. Where applicable, measurement lines were positioned perpendicular to the long axis of the implant to ensure standardized assessment of buccal bone thickness.

Assessment of Buccal Bone Dehiscence

Buccal bone dehiscence was defined as a loss or absence of the buccal cortical plate extending from the crestal aspect toward the implant surface. The presence or absence of dehiscence was recorded for each implant site. For sites demonstrating dehiscence, the vertical extent of the defect was measured from the crestal bone margin to the most apical extent of the exposed implant surface along the implant long axis. The measurements were recorded in millimetres.

Assessment of Buccal Bone Fenestration

Buccal bone fenestration was defined as a localized area of buccal cortical bone loss involving the implant surface, with preservation of the surrounding crestal and apical cortical bone. The presence or absence of fenestration was recorded for each implant site. For sites demonstrating fenestration, the fenestration width was defined as the greatest horizontal dimension of the cortical bone defect, measured according to the orientation of the defect. The fenestration depth was defined as the greatest distance from the outer surface of the implant to the external boundary of the remaining buccal cortical bone at the site of the defect. All measurements were recorded in millimetres. Measurements were performed on multiplanar reconstructed CBCT images, using the cross-sectional, sagittal, and coronal views in which the fenestration was most clearly visualized. The implant long axis was used as the principal reference axis, and measurement lines were positioned perpendicular to the implant long axis wherever applicable.

For each fenestration, the reconstructed sections were reviewed to identify the section demonstrating the greatest extent of the defect. The maximum measurable width and depth observed across the relevant sections were recorded in millimetres and used for statistical analysis.

Observer Assessment and Calibration
CBCT image evaluation was performed by two observers experienced in dentomaxillofacial radiology. Before the formal assessment, the observers underwent a calibration exercise using 10 representative CBCT cases (10% of the total sample) to standardize the identification and measurement of buccal bone defects. For assessment of measurement reliability, 20 CBCT scans (20% of the total sample) were randomly selected and re-evaluated by the same observers after a 2-week interval. Intra-observer and inter-observer agreement were assessed using the intraclass correlation coefficient (ICC) for continuous measurements and Cohen's kappa coefficient for categorical assessments, including the presence or absence of dehiscence and fenestration.

Blinding
The observers were blinded to the clinical information and other study variables during CBCT assessment. Image evaluation was performed using coded datasets to minimize potential observer bias.

Assessment of Buccal Bone Thickness
Buccal cortical bone thickness was measured at standardized locations adjacent to the implant using CBCT cross-sectional images. Measurements were recorded in millimetres. The presence of cortical defects was assessed in relation to the measured buccal bone thickness.

Assessment of Bone Defects
For implant sites demonstrating buccal bone dehiscence or fenestration, the location and extent of the defect were evaluated. The dimensions of fenestrations, including width and depth, were measured on CBCT images. The distribution of dehiscence and fenestration was subsequently compared according to implant location.

Maxillary and Mandibular Comparison
The implant sites were categorized according to their location in the maxilla or mandible. The frequency of buccal bone dehiscence and fenestration was compared between the two groups to identify differences associated with jaw location. Regional variations in the occurrence of cortical defects were also evaluated.

Statistical Analysis
All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables, including age and buccal bone thickness, were expressed as mean ± standard deviation (SD), whereas categorical variables were summarized as frequencies and percentages. The Chi-square test was used to assess the association between implant location and the presence of buccal bone dehiscence or fenestration. An independent-samples t-test was used to compare buccal bone thickness between implant sites with and without dehiscence. Intra-observer and inter-observer reliability were assessed using ICC and Cohen's kappa coefficient, as appropriate. A two-sided p-value < 0.05 was considered statistically significant. mention each participant has single implant site.

Results
Table 1 & Figure 1 present the demographic characteristics of the study population. A total of 100 participants/implant sites were evaluated in the present study, representing the complete study sample. The mean age was 16.4 ± 1.4 years. Among the participants, 54 (54.0%) were male and 46 (46.0%) were female, demonstrating a marginally higher proportion of male participants.

Table 1: Study population and demographic characteristics

Parameter	n	Percentage / Mean ± SD
Total participants/implants	100	100.0%
Age (years)	—	16.4 ± 1.4
Male	54	54.0%
Female	46	46.0%

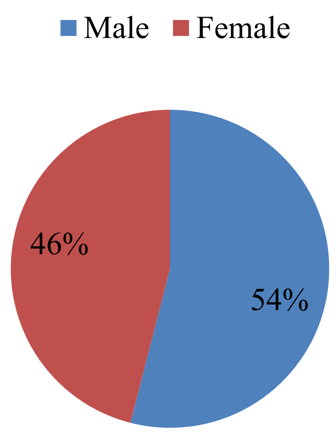

Figure 1: Gender distribution of the study participants

Table 2 & Figure 2 show the anatomical distribution of the 100 dental implants evaluated in the study. The maxillary anterior region had the highest number of implants, comprising 35 (35.0%) of the total. The maxillary posterior and mandibular posterior regions each accounted for 25 implants (25.0%). The mandibular anterior region had the lowest representation, with 15 implants (15.0%). Overall, 60 implants (60.0%) were placed in the maxilla, while 40 implants (40.0%) were located in the mandible.

Table 2: Distribution of dental implants according to site

Implant site	n	%
Maxillary anterior	35	35%
Maxillary posterior	25	25%
Mandibular anterior	15	15%
Mandibular posterior	25	25%
Total	100	100.0%

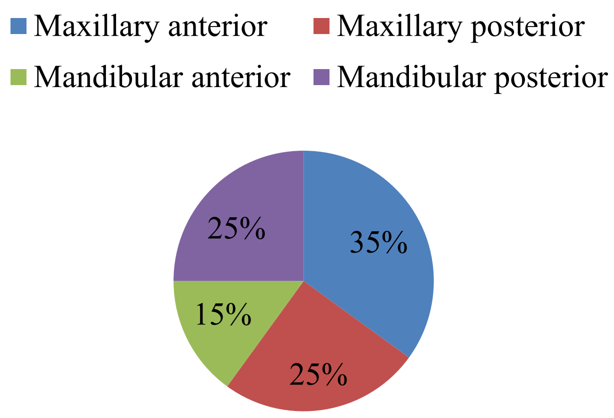

Figure 2: Anatomical distribution of dental implants according to the maxillary and mandibular anterior and posterior regions

Table 3 & Figure 3 present the CBCT-based assessment of buccal bone defects at the 100 implant sites included in the study. Buccal bone dehiscence was the most commonly detected finding, occurring at 24 sites (24.0%), followed by buccal bone fenestration, which was identified at 12 sites (12.0%). Both defects were simultaneously present at 5 sites (5.0%). Overall, 31 implant sites (31.0%) exhibited at least one form of buccal bone defect, whereas 69 sites (69.0%) showed no evidence of either dehiscence or fenestration on CBCT examination. These findings indicate that most implant sites had no detectable buccal bone defects, with dehiscence occurring more frequently than fenestration in the study population.

Table 3: Overall CBCT prevalence of buccal bone dehiscence and fenestration

CBCT finding	n	%
Dehiscence	24	24.0%
Fenestration	12	12.0%
Both dehiscence and fenestration	5	5.0%
At least one defect	31	31.0%
Neither defect	69	69.0%

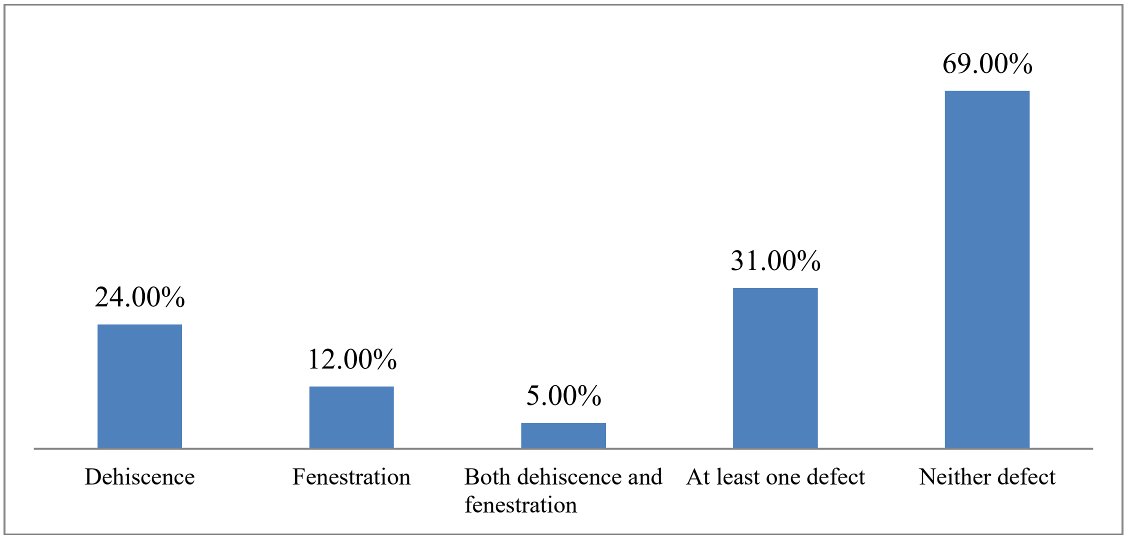

Figure 3: CBCT-based distribution of buccal bone dehiscence and fenestration among the evaluated dental implant sites

Table 4 & Figure 4 present the CBCT-based assessment of buccal bone dehiscence across the evaluated implant sites. Dehiscence was identified in 24 of 100 implant sites (24.0%). The highest prevalence was recorded in the mandibular anterior region, particularly among the incisors, where 9 of 15 sites (60.0%) exhibited dehiscence. In the mandibular posterior region, dehiscence was detected in 6 of 25 sites (24.0%). In the maxilla, dehiscence was observed in 3 of 35 anterior sites (8.6%) and 6 of 25 posterior sites (24.0%). Overall, buccal bone dehiscence occurred more frequently in mandibular implant sites, with the greatest site-specific prevalence observed in the mandibular anterior region.

Table 4: Site-wise distribution of buccal bone dehiscence

Site	Dehiscence, n (%)	No dehiscence, n (%)
Maxillary anterior	3 (8.6%)	32 (91.4%)
Maxillary posterior	6 (24.0%)	19 (76.0%)
Mandibular anterior	9 (60.0%)	6 (40.0%)
Mandibular posterior	6 (24.0%)	19 (76.0%)
Total	24 (24.0%)	76 (76.0%)

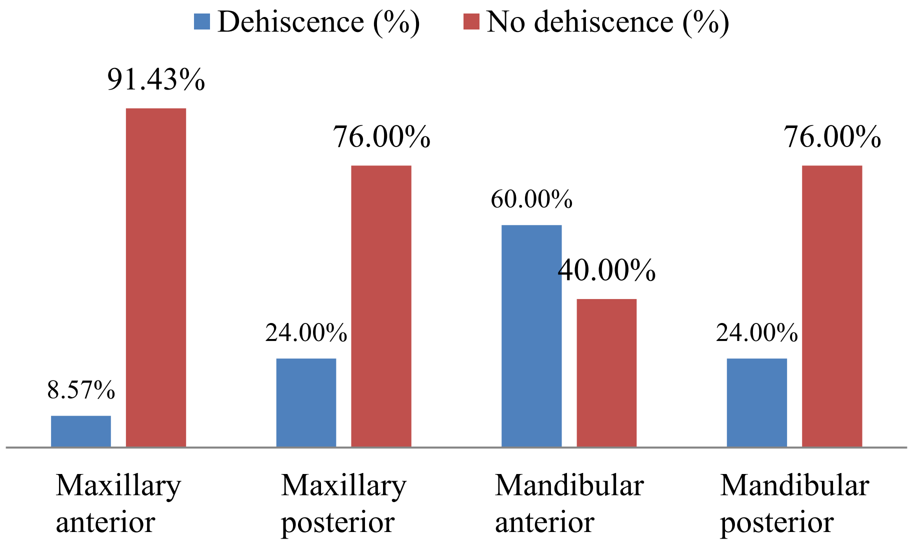

Figure 4: Regional distribution of buccal bone dehiscence among dental implant sites based on CBCT evaluation

Table 5 & Figure 5 present the site-wise distribution of buccal bone fenestration among the 100 implant sites evaluated using CBCT. Buccal bone fenestration was identified in 12 sites (12.0%), whereas 88 sites (88.0%) showed no evidence of fenestration. The maxillary posterior region demonstrated the highest site-specific prevalence of fenestration, with 4 of 25 sites (16.0%) affected. This was followed by the maxillary anterior region, where fenestration was observed in 5 of 35 sites (14.3%). In the mandible, fenestration was detected in 1 of 15 mandibular anterior sites (6.7%) and 2 of 25 mandibular posterior sites (8.0%). Overall, fenestration was observed more frequently in the maxilla (15.0%) than in the mandible (7.5%). Thus, the highest site-specific prevalence was recorded in the maxillary posterior region, while the mandibular anterior region showed the lowest prevalence.

Table 5: Site-wise distribution of buccal bone fenestration

Site	Fenestration, n (%)	No fenestration, n(%)
Maxillary anterior	5 (14.3%)	30 (85.7%)
Maxillary posterior	4 (16.0%)	21 (84.0%)
Mandibular anterior	1 (6.7%)	14 (93.3%)
Mandibular posterior	2 (8.0%)	23 (92.0%)
Total	12 (12.0%)	88 (88

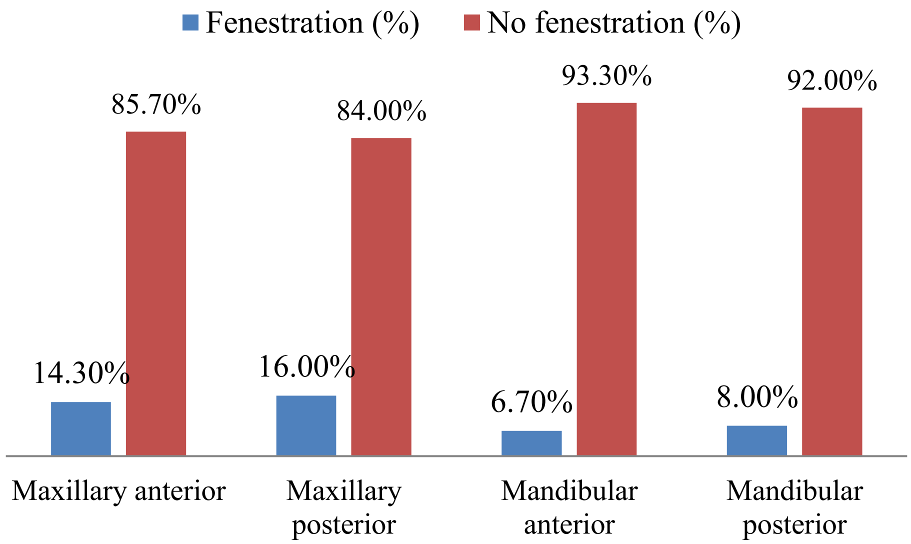

Figure 5: Site-wise distribution of buccal bone fenestration among dental implant sites based on CBCT assessment

Table 6 & Figure 6 compare the prevalence of buccal bone dehiscence and fenestration between maxillary and mandibular implant sites. Buccal bone dehiscence was more frequently detected in the mandible, affecting 15 of 40 sites (37.5%), compared with 9 of 60 maxillary sites (15.0%). This difference was statistically significant (χ^2 = 6.66, p = 0.010). In contrast, buccal bone fenestration occurred more often in the maxilla, being identified in 9 of 60 sites (15.0%), compared with 3 of 40 mandibular sites (7.5%). However, this difference did not reach statistical significance (χ^2 = 1.28, p = 0.258). Overall, buccal bone dehiscence demonstrated a significantly greater occurrence in mandibular implant sites, with the highest frequency noted in the mandibular anterior region. Buccal bone fenestration was more commonly observed in maxillary sites, particularly in the canine and molar regions, although the difference between the arches was not statistically significant.

Table 6: Comparison of maxillary and mandibular sites

Defect	Maxilla n/N (%)	Mandible n/N (%)	χ^2	p-value
Dehiscence	9/60 (15.0%)	15/40 (37.5%)	6.66	0.010
Fenestration	9/60 (15.0%)	3/40 (7.5%)	1.28	0.258

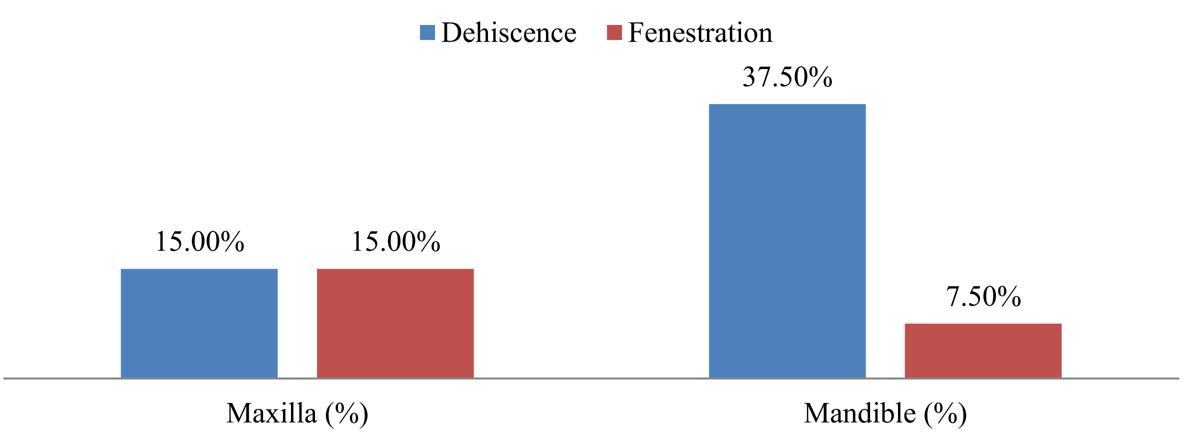

Figure 6: Comparison of the prevalence of buccal bone dehiscence and fenestration between maxillary and mandibular implant sites

Table 7 & Figure 7 present the CBCT-based comparison of buccal bone thickness between implant sites with and without dehiscence. The mean buccal bone thickness was substantially lower at sites exhibiting dehiscence (0.72 ± 0.15 mm) than at sites without dehiscence (1.39 ± 0.32 mm). The observed mean difference was 0.67 mm, indicating a considerable reduction in buccal bone thickness at sites affected by dehiscence. This difference was statistically significant ($t = -9.894$, $p < 0.001$), demonstrating that implant sites with buccal bone dehiscence had significantly thinner buccal bone than sites without detectable dehiscence on CBCT examination.

Table 7: Buccal bone thickness in sites with and without dehiscence

Group	n	Buccal Bone Thickness (mm), Mean ± SD	Mean Difference (mm)	t-value	p-value
Dehiscence present	24	0.72 ± 0.15	0.67	−9.894	<0.001
Dehiscence absent	76	1.39 ± 0.32			

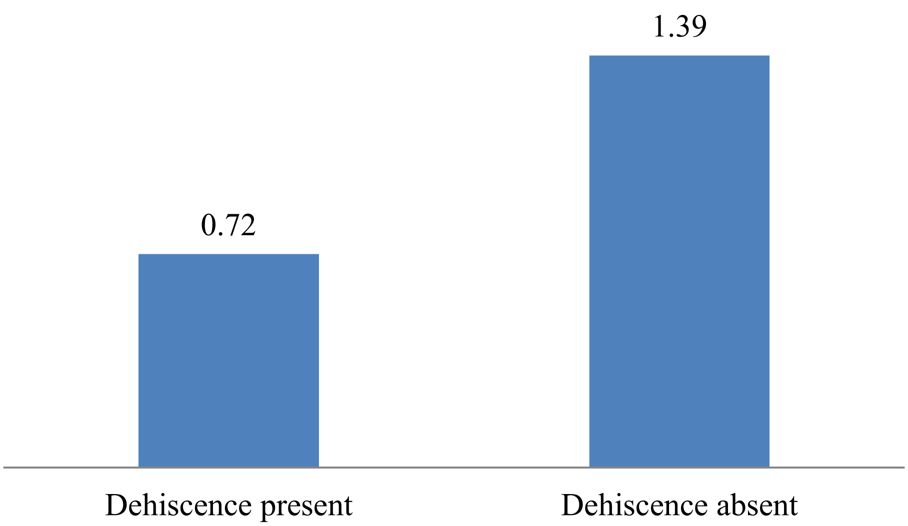

Figure 7: Comparison of mean buccal bone thickness between implant sites with and without buccal bone dehiscence based on CBCT assessment

Table 8 & Figure 8 present the dimensions of buccal bone fenestrations identified on CBCT examination. Among the 12 implant sites exhibiting fenestration, the mean fenestration width was 2.02 ± 0.61 mm, with values ranging from 0.9 to 3.0 mm. The mean depth/vertical extent of the defects was 3.09 ± 0.79 mm, with a range of 1.8 to 4.5 mm. These findings indicate that the fenestrations generally exhibited a greater vertical extent than transverse width, suggesting that the defects predominantly extended along the vertical dimension of the buccal alveolar bone.

Table 8: Dimensions of buccal bone fenestrations

Parameter	n	Mean ± SD (mm)	Range
Fenestration width	12	2.02 ± 0.61	0.9–3.0
Fenestration depth/vertical extent	12	3.09 ± 0.79	1.8–4.5

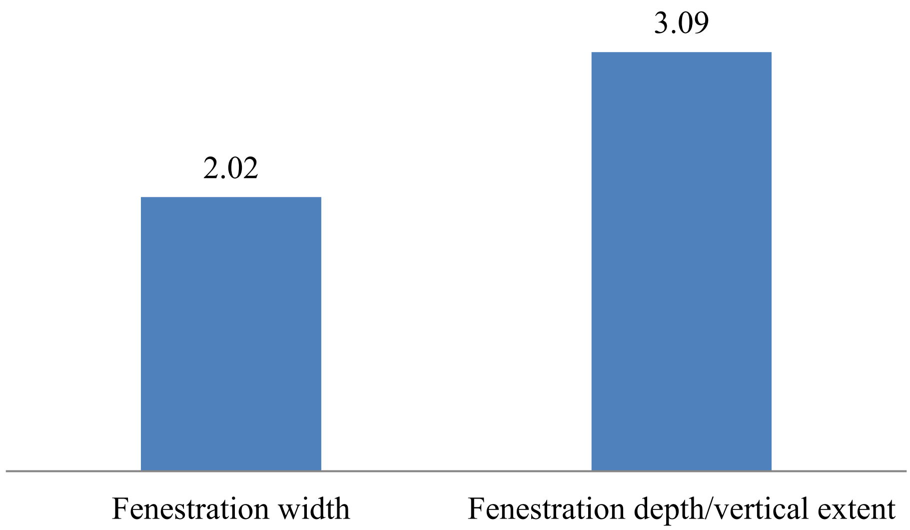

Figure 8: Mean dimensions of buccal bone fenestrations, including width and depth/vertical extent, based on CBCT assessment

Discussion

The present study investigated buccal cortical bone dehiscence and fenestration around dental implants in adolescent patients using CBCT. Both types of facial cortical defects were identified in the evaluated implant sites, with dehiscence occurring more frequently than fenestration. A considerable proportion of implant sites demonstrated at least one form of buccal cortical defect. These findings highlight the importance of 3D imaging for evaluating the facial peri-implant bone, particularly because thin or discontinuous cortical areas may not be adequately appreciated on conventional 2D radiographs.

The facial cortical plate represents an important component of peri-implant hard-tissue architecture. González-Martín et al. (2016) [10], in an experimental computed tomography (CT) study, examined the relationship between implant position and the surrounding buccal bone and emphasized the relevance of facial bone thickness in peri-implant assessment. Their observations support the need to evaluate the facial bony envelope when assessing implant position and surrounding anatomy. Consistent with this principle, the present study demonstrated that implant sites affected by dehiscence had thinner buccal bone than sites without dehiscence. This finding suggests a close anatomical relationship between reduced facial bone thickness and the occurrence of cortical dehiscence. Nevertheless, because the present investigation was cross-sectional, this association should not be interpreted as evidence of a direct causal relationship.

The distribution of buccal dehiscence also differed between the maxilla and mandible, with the defect being more commonly identified at mandibular implant sites. The mandibular anterior region demonstrated the greatest regional occurrence of dehiscence. This pattern may be related to variations in facial cortical anatomy, alveolar ridge dimensions, implant positioning, or the proximity of the implant to the facial cortical boundary. However, these potential contributing factors were not specifically examined in the present study. Therefore, the regional distribution observed should be interpreted as an anatomical observation rather than evidence that any particular factor was responsible for the development of dehiscence.

The spatial relationship between an implant and the surrounding facial bone is particularly important because an implant positioned close to the cortical boundary may have inadequate buccal bone coverage. CBCT allows visualization of the implant and surrounding structures in multiple planes, thereby facilitating assessment of the 3D relationship between the implant and the facial cortical plate. Schubert et al. (2019) [11] discussed digital implant planning and guided surgical approaches that enable 3D assessment and accurate transfer of planned implant positions. Although their investigation focused primarily on digital planning and guided implant placement rather than cortical defects, their findings reinforce the importance of 3D evaluation during implant assessment.

Fenestration demonstrated a different distribution pattern from dehiscence, being observed more frequently in the maxilla than in the mandible. However, the difference between the jaws was not statistically significant. The greatest occurrence was noted in the maxillary posterior region. Therefore, the apparent predominance of fenestration in the maxilla should be considered a descriptive observation rather than evidence of a significant relationship between fenestration and jaw location. The morphological evaluation of the fenestrations showed that these defects varied in their dimensions and configuration. In general, the defects demonstrated greater vertical extension than transverse width, suggesting that the cortical deficiencies tended to extend along the vertical aspect of the implant rather than predominantly in the horizontal direction. Distinguishing fenestration from dehiscence is clinically important because the two defects represent different patterns of cortical involvement. Fenestration refers to a localized area of cortical bone loss in which the marginal portion of the cortical plate remains intact, whereas dehiscence involves an extension of the defect toward the crestal aspect of the alveolar bone.

Variations in peri-implant bone-defect morphology have also been described by Monje et al. (2019) [12], who reported differences in the configuration and severity of bone defects associated with peri-implant disease. Although their population and clinical context were different from those of the present study, their findings support the concept that peri-implant bone defects can exhibit diverse morphological patterns. Accordingly, evaluating the location, configuration, and extent of a cortical defect may provide more useful anatomical information than simply recording whether a defect is present or absent. The present study adopted a similar approach by examining the distribution and morphology of buccal cortical defects.

The importance of maintaining peri-implant hard and soft tissues has been emphasized by Berglundh et al. (2018) [13], whose consensus report discussed the biological characteristics of peri-implant health and disease as well as considerations for clinical diagnosis. Although peri-implantitis and clinical inflammatory outcomes were not investigated in the present study, assessment of the facial cortical bone provides important structural information regarding the peri-implant environment. The identification of cortical deficiencies may therefore contribute to a more comprehensive understanding of the anatomical conditions surrounding an implant.

Hu et al. (2017) [14] evaluated immediate implant placement in posterior extraction sockets in relation to the presence or absence of buccal bone dehiscence and demonstrated the clinical relevance of pre-existing facial bone deficiencies. Although their study differed from the present investigation with respect to population, clinical setting, and treatment protocol, it reinforces the importance of identifying deficiencies in the facial cortical plate during implant assessment. The present findings similarly indicate that the integrity and morphology of the buccal cortical bone should receive careful attention during evaluation of implant sites.

The application of CBCT for assessment of peri-implant bone defects has been discussed by Costa et al. (2023) [15], who highlighted its ability to provide 3D information while also acknowledging limitations related to image quality and artifacts produced by metallic structures. These limitations are particularly relevant when evaluating thin cortical bone, where image artifacts or inadequate spatial resolution may influence defect detection. Although appropriate image-quality criteria were considered in the present study, subtle cortical irregularities should nevertheless be interpreted with caution. Standardized imaging protocols and appropriate image reconstruction are therefore important for reliable assessment.

The findings of this study are especially relevant to adolescent implant patients because this population may still experience changes in craniofacial and dentoalveolar development. Unlike natural teeth, osseointegrated implants do not participate in normal eruptive or positional changes associated with growth. Consequently, careful assessment of the available alveolar bone and the 3D position of an implant is particularly important in younger patients. However, the present study was cross-sectional and did not include longitudinal assessment of skeletal or alveolar development. Therefore, the identified cortical defects cannot be directly attributed to ongoing growth.

A number of anatomical, implant-related, and treatment-related variables may influence the development or detection of buccal cortical defects. These include implant dimensions, buccolingual position, implant angulation, ridge morphology, surgical technique, and characteristics of the surrounding soft tissues. Such factors were not comprehensively assessed in the present investigation. Therefore, the relationship between reduced buccal bone thickness and dehiscence should be interpreted primarily as an anatomical association rather than as evidence of a specific etiological mechanism.

Overall, the findings indicate that CBCT is a valuable imaging modality for 3D evaluation of the buccal cortical bone surrounding dental implants in adolescent patients. The greater occurrence of dehiscence in mandibular implant sites and the association between thinner buccal bone and dehiscence emphasize the importance of evaluating the facial bony envelope before and around implant placement. Recognition and characterization of cortical defects may assist in understanding peri-implant anatomy and identifying sites with limited facial bone coverage. Future multicentre and prospective investigations involving larger populations, standardized CBCT acquisition protocols, and comprehensive assessment of anatomical, implant-related, and soft-tissue variables are warranted to better determine the factors associated with buccal bone dehiscence and fenestration and to establish their long-term clinical significance in adolescent implant patients.

Limitations

Several limitations of the present investigation should be acknowledged. The study included 100 implant sites, which represents a relatively modest sample and may have limited the statistical strength of some subgroup comparisons. Consequently, the study was carried out at a single tertiary care centre & findings may not be fully representative of broader patient populations. In addition, the implant sites were not equally distributed between the jaws, with a greater proportion located in the maxilla than in the mandible. The relatively small number of sites in specific anatomical regions, particularly the mandibular anterior region, may have affected the reliability of regional comparisons.

Another limitation is the reliance on CBCT-based evaluation for the detection and measurement of buccal cortical defects. The visualization of small areas of cortical bone loss can be influenced by technical characteristics of the scan, including voxel size, spatial resolution, image quality, metallic artifacts, and differences in image interpretation. Although CBCT provided 3D information regarding the buccal bone, the present study did not assess several clinical and implant-specific parameters that could potentially influence the development of cortical defects. These included implant diameter, precise 3D implant position, implant angulation, buccolingual inclination, preoperative ridge width, implant placement approach, and the thickness of the surrounding soft tissues. Furthermore, the observational nature of the study limits the ability to establish a cause-and-effect relationship between buccal bone thickness and the occurrence of dehiscence or fenestration. The finding that sites with dehiscence were associated with reduced buccal bone thickness indicates an association but does not establish that decreased bone thickness directly caused the defect. The investigation was also primarily concerned with the radiographic characteristics and dimensions of buccal bone dehiscence and fenestration. Clinical outcomes that may be associated with these defects, including peri-implant marginal bone changes, mucosal or gingival recession, esthetic complications, and long-term implant stability or survival, were not evaluated. Therefore, the clinical implications of the radiographic findings cannot be determined from the present study alone.

Future research should involve larger, well-balanced study populations and standardized CBCT acquisition and assessment protocols. Incorporating detailed anatomical, implant-related, and soft-tissue parameters, together with prospective clinical follow-up, would provide a more comprehensive understanding of the factors associated with buccal bone defects and their potential influence on long-term peri-implant health.

Conclusion

CBCT enabled 3D assessment of buccal cortical bone defects around dental implants in adolescent patients. Buccal bone dehiscence was significantly more prevalent in mandibular than maxillary implant sites and was associated with significantly reduced buccal bone thickness. Fenestration was more frequent in the maxilla, although the difference was not statistically significant. These findings support the value of CBCT for evaluating buccal cortical bone morphology during implant assessment and planning. However, the cross-sectional design and limited sample size restrict causal and long-term clinical interpretation. Larger prospective, multicentre studies with standardized imaging and long-term follow-up are needed to clarify the clinical significance of these defects and their relationship with peri-implant outcomes.

Conflicts of Interest: Nil
Financial Support: None

References

1. Thilander B, Odman J, Gröndahl K, Friberg B. Osseointegrated implants in adolescents. An alternative in replacing missing teeth? Eur J Orthod. 1994 Apr;16(2):84-95. doi: 10.1093/ejo/16.2.84. PMID: 8005203.
2. Heij DG, Opdebeeck H, van Steenberghe D, Kokich VG, Belser U, Quirynen M. Facial development, continuous tooth eruption, and mesial drift as compromising factors for implant placement. Int J Oral Maxillofac Implants. 2006 Nov-Dec;21(6):867-78. PMID: 17190296.
3. Westwood RM, Duncan JM. Implants in adolescents: a literature review and case reports. Int J Oral Maxillofac Implants. 1996 Nov-Dec;11(6):750-5. PMID: 8990636.
4. Peterson AG, Wang M, Gonzalez S, Covell DA Jr, Katancik J, Sehgal HS. An In Vivo and Cone Beam Computed Tomography Investigation of the Accuracy in Measuring Alveolar Bone Height and Detecting Dehiscence and Fenestration Defects. Int J Oral Maxillofac Implants. 2018 Nov/Dec;33(6):1296-1304. doi: 10.11607/jomi.6633. PMID: 30427960.
5. Benic GI, Elmasry M, Hämmerle CH. Novel digital imaging techniques to assess the outcome in oral rehabilitation with dental implants: a narrative review. Clin Oral Implants Res. 2015 Sep;26 Suppl 11:86-96. doi: 10.1111/clr.12616. Epub 2015 May 26. PMID: 26010421.
6. Domic D, Bertl K, Ahmad S, Schropp L, Hellén-Halme K, Stavropoulos A. Accuracy of cone-beam computed tomography is limited at implant sites with a thin buccal bone: A laboratory study. J Periodontol. 2021 Apr;92(4):592-601. doi: 10.1002/JPER.20-0222. Epub 2020 Sep 16. PMID: 32846005; PMCID: PMC8247288.
7. Schriber M, Yeung AWK, Suter VGA, Buser D, Leung YY, Bornstein MM. Cone beam computed tomography artefacts around dental implants with different materials influencing the detection of peri-implant bone defects. Clin Oral Implants Res. 2020 Jul;31(7):595-606. doi: 10.1111/clr.13596. Epub 2020 Mar 23. PMID: 32147872.
8. Salemi F, Jamalpour MR, Eskandarloo A, Tapak L, Rahimi N. Efficacy of Metal Artifact Reduction Algorithm of Cone-Beam Computed Tomography for Detection of Fenestration and Dehiscence around Dental Implants. J Biomed Phys Eng. 2021 Jun 1;11(3):305-314. doi: 10.31661/jbpe.v0i0.2102-1284. PMID: 34189119; PMCID: PMC8236107.
9. Popińska Z, Ślusarczyk D, Żmuda B, Jakubowska W, Pisera P, Kiełkowicz A, et al. Cone-beam computed tomography in implant dentistry - guidelines, current concepts and limitations for practice. J Educ Health Sport [Internet]. 2024 Jan. 5 [cited 2026 Aug. 30];51:21-36. Available from: https://apcz.umk.pl/JEHS/article/view/47722
10. González-Martín O, Oteo C, Ortega R, Alandez J, Sanz M, Veltri M. Evaluation of peri-implant buccal bone by computed tomography: an experimental study. Clin Oral Implants Res. 2016 Aug;27(8):950-5. doi: 10.1111/clr.12663. Epub 2015 Jul 14. PMID: 26178780.
11. Schubert O, Schweiger J, Stimmelmayr M, Nold E, Güth JF. Digital implant planning and guided implant surgery - workflow and reliability. Br Dent J. 2019 Jan 25;226(2):101-108. doi: 10.1038/sj.bdj.2019.44. PMID: 30679852.
12. Monje A, Pons R, Insua A, Nart J, Wang HL, Schwarz F. Morphology and severity of peri-implantitis bone defects. Clin Implant Dent Relat Res. 2019 Aug;21(4):635-643. doi: 10.1111/cid.12791. Epub 2019 May 14. PMID: 31087457.
13. Berglundh T, Armitage G, Araujo MG, Avila-Ortiz G, Blanco J, Camargo PM, Chen S, Cochran D, Derks J, Figuero E, Hämmerle CHF, Heitz-Mayfield LJA, Huynh-Ba G, Iacono V, Koo KT, Lambert F, McCauley L, Quirynen M, Renvert S, Salvi GE, Schwarz F, Tarnow D, Tomasi C, Wang HL, Zitzmann N. Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. J Clin Periodontol. 2018 Jun;45 Suppl 20:S286-S291. doi: 10.1111/jcpe.12957. PMID: 29926491.
14. Hu C, Gong T, Lin W, Yuan Q, Man Y. Immediate implant placement into posterior sockets with or without buccal bone dehiscence defects: A retrospective cohort study. J Dent. 2017 Oct;65:95-100. doi: 10.1016/j.jdent.2017.07.010. Epub 2017 Jul 21. PMID: 28739320.
15. Costa JA, Mendes JM, Salazar F, Pacheco JJ, Rompante P, Câmara MI. Analysis of peri-implant bone defects by using cone beam computed tomography (CBCT): an integrative review. Oral Radiol. 2023 Jul;39(3):455-466. doi: 10.1007/s11282-023-00683-w. Epub 2023 Apr 14. PMID: 37058184; PMCID: PMC10244286.