

# AN ASSESSMENT OF ANATOMICAL VARIATIONS AFFECTING IMPLANT PLACEMENTS USING CBCT: A RETROSPECTIVE STUDY

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## ABSTRACT

**Background:** Anatomical variations in the maxilla and mandible can affect dental implant placement and may increase the risk of complications if not identified during treatment planning. CBCT scans provide three-dimensional imaging and helps in detecting of such variations accurately.

**Aim:** To assess the prevalence of anatomical variations noticed when planning implant placements using CBCT images.

**Materials and Methods** A retrospective observational study was conducted on CBCT records of 50 patients planned for dental implants. CBCT scans were evaluated for ridge limitations and anatomical variations including mandibular canal proximity, anterior loop, bifid mandibular canal, maxillary sinus proximity, sinus septa, and nasopalatine canal involvement. Evidently, implant planning changes were made after CBCT scans were acquired. Data were analyzed using descriptive statistics and Chi-square test. A p-value <0.05 was considered statistically significant.

**Results:** Reduced bone height was seen in 36% and reduced ridge width in 32% of cases. Mandibular canal proximity (<2 mm) was present in 20%, anterior loop in 16%, and bifid mandibular canal in 6%. Maxillary sinus proximity (<2 mm) was noted in 24% and sinus septa was observed in 12%. CBCT scanning resulted in at least one treatment plan modification in 66% of patients. Sinus-related constraints were significantly associated with maxillary cases, while canal proximity and anterior loop were significantly associated with mandibular cases (p<0.05).

**Conclusion:** The use of CBCT in implant patients revealed clinically significant anatomical variations that frequently altered treatment planning. Its application enhanced preoperative risk assessment and facilitated safer, more accurate implant placement decisions.

**Keywords:** Cone beam computed tomography, Dental implants, Anatomical variations, Mandibular canal, Maxillary sinus, Implant planning

**How to cite this article:** Rai NP, Shivakumar GC, Nambiar P, Fakhra I, Agarwal A, Dhayanidhi A., An Assessment of Anatomical Variations Affecting Implant Placements Using CBCT: A Retrospective Study. Int J Drug Deliv Technol. 2026;16(7): 1582-1588; DOI: 10.25258/ijddt.16.7.172

## INTRODUCTION

Dental implant therapy has become a predictable and widely accepted treatment for replacing missing teeth. However, the success of implant placement depends heavily on correct diagnosis and careful treatment planning. One of the most important steps before implant surgery is evaluating the available bone and identifying vital anatomical structures near the implant site. Anatomical variations in the maxilla and mandible can increase the risk of complications such as nerve injury, bleeding, sinus perforation, and implant failure if they are not detected

during planning. Therefore, accurate imaging is essential for safe and successful implant placement.

Conventional two-dimensional radiographs such as periapical and panoramic radiographs are commonly used for implant planning, but they have limitations. These include magnification, distortion, superimposition of structures, and inability to provide true three-dimensional information. Cone Beam Computed Tomography (CBCT) has improved implant planning by providing three-dimensional imaging of the jaws with relatively lower radiation dose compared to conventional medical CT. CBCT images allows

accurate assessment of bone height and width, bone morphology, and the spatial relationship between the planned implant and nearby anatomical structures.<sup>1</sup>

Several anatomical structures are clinically important during implant planning. In the mandible, the inferior alveolar canal and mental foramen must be evaluated carefully to avoid neurosensory complications. Variations such as bifid mandibular canals, accessory canals, and differences in canal course have been reported, and these may not be easily visible on routine 2D imaging.<sup>2-4</sup> In the maxilla, the proximity of the maxillary sinus and the morphology of the nasopalatine canal can influence implant placement, especially in posterior and anterior implant sites. CBCT image provides clear visualization of these regions and supports better decision-making regarding implant dimensions and surgical approach.<sup>5-7</sup>

Although CBCT is widely used in implant dentistry, there is still a need to understand how frequently clinically relevant anatomical variations occur in implant patients and how often they may influence implant placement decisions. Identifying the prevalence of such variations can support evidence-based use of CBCT scanning and improve patient safety. Therefore, the present retrospective study aims to assess the anatomical variations affecting implant placement using CBCT and determine their prevalence in patients planned for dental implants.

## MATERIALS AND METHODS

This study was a retrospective observational study conducted to assess the prevalence of anatomical variations on CBCT scans that could influence dental implant placement. The study was carried out in the Department of Oral Medicine and Radiology of People's College of Dental Sciences and Research Centre, People's University, Bhopal. CBCT records of patients referred for implant evaluation were retrieved from the departmental database. The data were collected retrospectively for an 8-month period.

Ethical clearance was obtained from the Institutional Ethics Committee prior to the start of the study. Patient confidentiality was maintained throughout the study. Only anonymized data were used for analysis. The study included CBCT scans of adult patients who had undergone——imaging for dental implant treatment planning. Each CBCT scan was evaluated for anatomical variations relevant to implant placement.

All eligible CBCT scans available during the study period were included. A final sample of 50 scans was analyzed.

### Inclusion criteria

CBCT records were included if they met the following criteria:

- Patients aged 18 years and above
- CBCT scans taken specifically for implant site assessment
- CBCT scans with adequate image quality for evaluation
- Presence of at least one potential implant site in the maxilla or mandible

### Exclusion criteria

CBCT scans were excluded in the following conditions:

- Scans with severe motion artifacts or poor image quality
- Patients with a history of major jaw surgery affecting anatomy
- Presence of extensive pathology or trauma in the implant site area
- Incomplete records or missing key clinical details

### Data collection procedure

CBCT records were retrieved. Patient details such as age and gender were recorded. Each scan was assessed for anatomical variations in the maxilla and mandible that could affect implant planning.

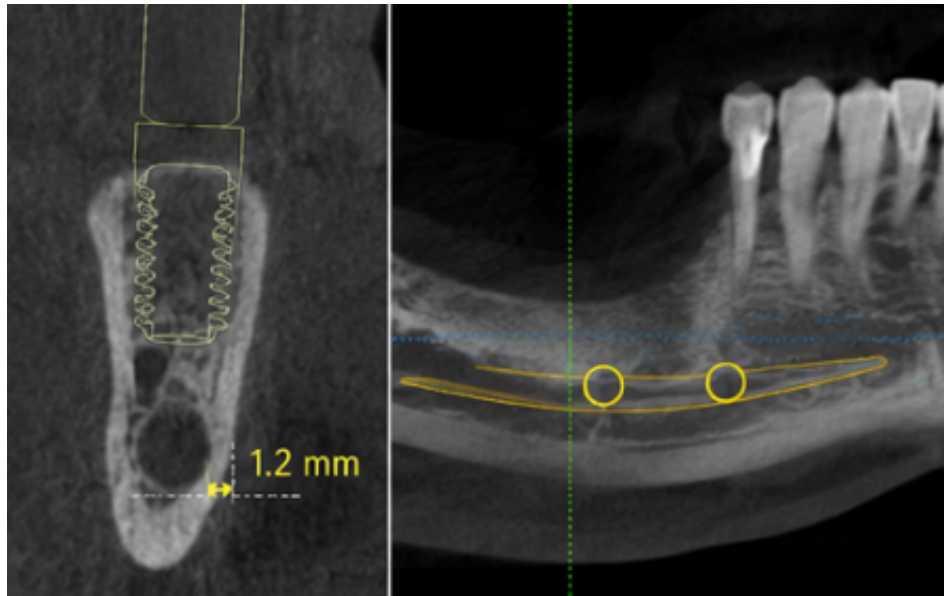
### CBCT parameters

All CBCT scans were obtained using the same CBCT machine (CARESTREAM). Standard imaging parameters such as field of view (FOV), voxel size, kVp, and mA were used as per protocol.

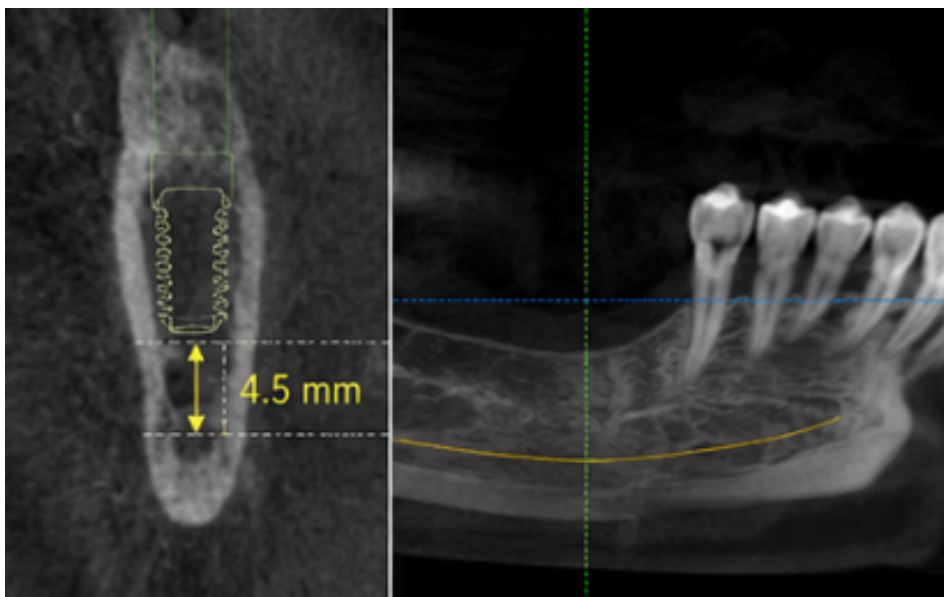
Study variables assessed were age, gender and CBCT anatomical variables. CBCT anatomical variables evaluated were

- Mandibular canal position and course
- Presence of bifid mandibular canal
- Anterior loop of mental nerve
- Accessory mental foramen (if present)
- Proximity of mandibular canal to implant site
- Maxillary sinus proximity to implant site
- Sinus septa (if present)
- Incisive foramen morphology in anterior maxilla
- Presence of undercuts or concavities affecting implant placement

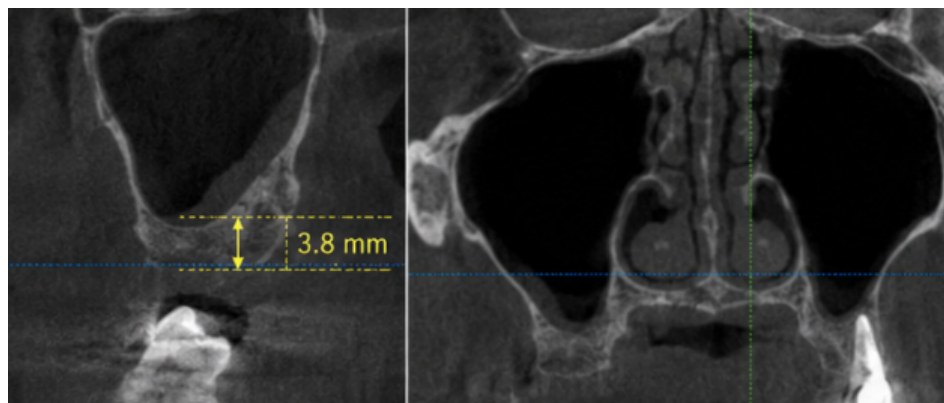
*Outcome measures* – The primary outcome was the prevalence of anatomical variations detected on CBCT that could influence implant placement. Secondary outcomes included the association of anatomical variations with age group, gender, and implant site region in maxilla and mandible. [ Fig 1-5]



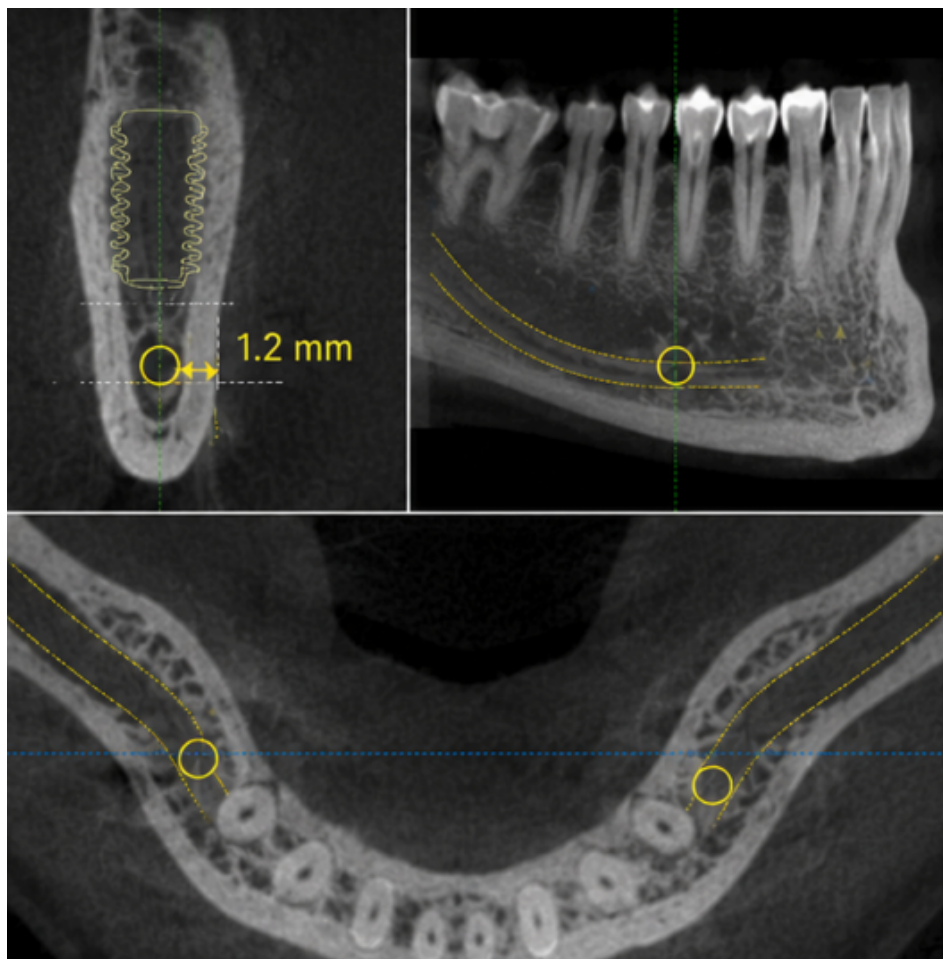
**Figure 1: Implant in close proximity to mandibular canal (<2mm)**



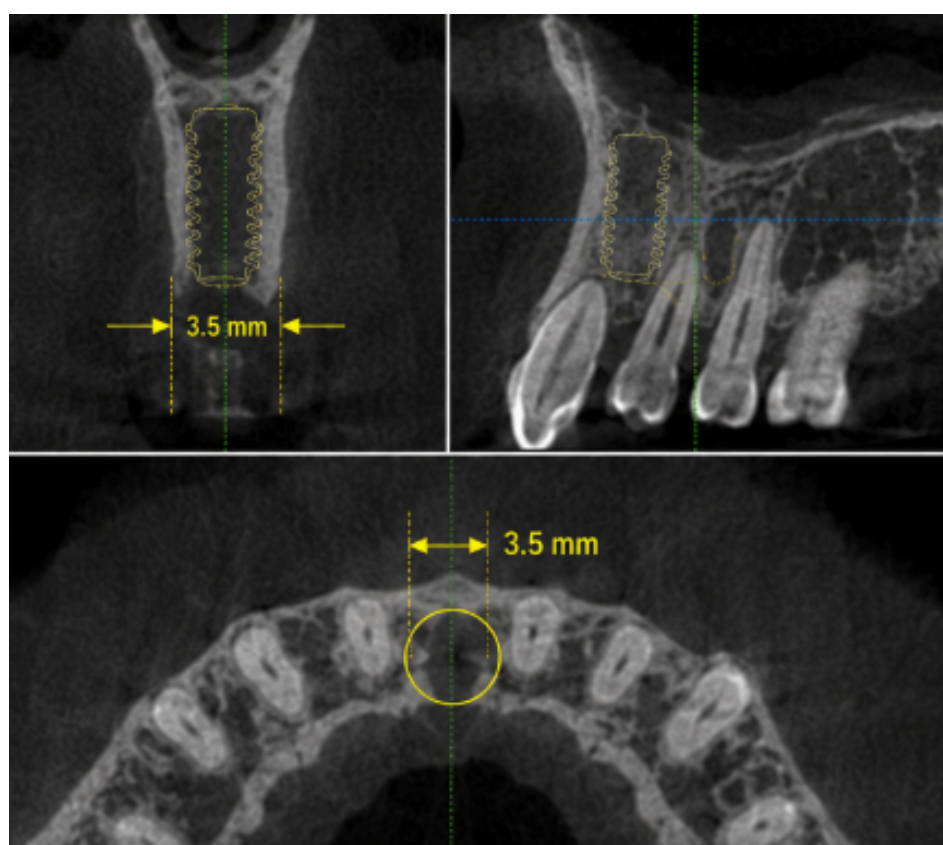
**Figure 2: Reduced vertical bone height (short implant or modification required)**



**Figure 3: Insufficient bone height under maxillary sinus (sinus lift required)**



**Figure 4: Implant site in close proximity to mandibular canal (<2mm) increasing the risk of nerve injury**



**Figure 5: Reduced ridge width – narrow implant indicated to ensure adequate stability**

The CBCT evaluations were performed by a trained examiner. To ensure reliability, a subset of scans was re-evaluated after a

time interval, and intra-examiner agreement was assessed using the kappa statistic.

Data were entered into Microsoft Excel and analyzed using SPSS software 25.0 version. Descriptive statistics were used to present frequencies and percentages. The association between categorical variables was tested using the Chi-square test. A p-value of <0.05 was considered statistically significant.

## RESULTS

In this retrospective CBCT-based study of 50 implant cases, most patients were aged 31–45 years and males formed a slightly higher proportion than females as seen in Table 1. The most

frequent anatomical constraints were reduced bone height (36%) and reduced ridge width (32%) as observed in Table 2. Mandibular canal proximity was seen in 20% of cases, while maxillary sinus proximity was present in 24% of cases. CBCT resulted in treatment plan modifications in 66% of cases, commonly involving changes in implant length, diameter, or angulation. Maxillary cases were significantly associated with sinus-related limitations, whereas mandibular cases were significantly associated with mandibular canal proximity and anterior loop presence.

**Table 1: Demographic profile of study participants**

| Variable                                 | Category | n  | %    |
|------------------------------------------|----------|----|------|
| Age group (years)                        | 18–30    | 12 | 24.0 |
|                                          | 31–45    | 18 | 36.0 |
|                                          | 46–60    | 14 | 28.0 |
|                                          | >60      | 6  | 12.0 |
| Gender                                   | Male     | 28 | 56.0 |
|                                          | Female   | 22 | 44.0 |
| Implant planning region (site evaluated) | Maxilla  | 24 | 48.0 |
|                                          | Mandible | 26 | 52.0 |

**Table 2: Prevalence of CBCT-detected anatomical variations affecting implant planning**

| Anatomical finding (CBCT)                                  | Present n (%) | Absent n (%) |
|------------------------------------------------------------|---------------|--------------|
| Reduced bone height requiring short implant / modification | 18 (36.0)     | 32 (64.0)    |
| Reduced ridge width requiring narrow implant               | 16 (32.0)     | 34 (68.0)    |
| Proximity to mandibular canal (<2 mm)                      | 10 (20.0)     | 40 (80.0)    |
| Anterior loop of mental nerve present                      | 8 (16.0)      | 42 (84.0)    |
| Bifid mandibular canal                                     | 3 (6.0)       | 47 (94.0)    |
| Maxillary sinus proximity (<2 mm)                          | 12 (24.0)     | 38 (76.0)    |
| Sinus septa present                                        | 6 (12.0)      | 44 (88.0)    |
| Incisive foramen close to implant Zone                     | 5 (10.0)      | 45 (90.0)    |
| Buccal/lingual undercut concavity at implant site          | 11 (22.0)     | 39 (78.0)    |

**Table 3: Implant planning modifications based on CBCT findings**

| Planning change after CBCT               | n  | %    |
|------------------------------------------|----|------|
| No change in original plan               | 17 | 34.0 |
| Implant length modified                  | 14 | 28.0 |
| Implant diameter modified                | 11 | 22.0 |
| Implant angulation modified              | 9  | 18.0 |
| Bone grafting required                   | 10 | 20.0 |
| Sinus lift required                      | 6  | 12.0 |
| Site avoided / alternative site selected | 4  | 8.0  |

Table 3 shows the implant treatment plan modifications following CBCT evaluation. Overall, CBCT influenced the treatment plan in a majority of cases, with implant length modification being the most common change (28.0%), followed by implant diameter modification (22.0%) and implant

angulation modification (18.0%). Bone grafting and sinus lift procedures were required in 20.0% and 12.0% of cases, respectively, whereas no change in the original treatment plan was observed in 34.0% of patients.

**Table 4: Association between region and major anatomical constraints**

| Finding                            | Maxilla<br>(n=24) n (%) | Mandible<br>(n=26) n (%) | p-value* |
|------------------------------------|-------------------------|--------------------------|----------|
| Sinus proximity (<2 mm)            | 12 (50.0)               | 0 (0)                    | <0.001   |
| Sinus septa                        | 6 (25.0)                | 0 (0)                    | 0.006    |
| Mandibular canal proximity (<2 mm) | 0 (0)                   | 10 (38.5)                | <0.001   |
| Anterior loop present              | 0 (0)                   | 8 (30.8)                 | 0.003    |
| Undercut concavity                 | 4 (16.7)                | 7 (26.9)                 | 0.39     |

\*Chi-square test;  $p < 0.05$  considered significant

Table 4 shows the association between the implant region and major anatomical constraints identified on CBCT. Maxillary implant sites demonstrated a significantly higher prevalence of maxillary sinus proximity (50.0%;  $p < 0.001$ ) and sinus septa (25.0%;  $p = 0.006$ ), whereas mandibular implant sites showed significantly greater mandibular canal proximity (38.5%;  $p < 0.001$ ) and presence of the anterior loop of the mental nerve (30.8%;  $p = 0.003$ ). No statistically significant association was observed between the implant region and the presence of buccal/lingual undercut concavity ( $p = 0.39$ ).

## DISCUSSION

The present retrospective CBCT-based study evaluated anatomical variations that can influence implant placement decisions in 50 patients. In our sample, the most frequent limiting factors were reduced bone height (36%) and reduced ridge width (32%). These findings are clinically relevant because inadequate ridge dimensions are common in partially edentulous patients due to post-extraction resorption, and they often require modifications in implant size or additional augmentation procedures. Similar observations have been reported in implant planning literature, where CBCT helps clinicians visualize ridge morphology more accurately than conventional radiographs and supports safer decision-making.<sup>8,9</sup>

In the mandible, proximity to the mandibular canal (<2 mm) was detected in 20% of cases, and an anterior loop of the mental nerve was present in 16% of cases. These findings highlight the importance of three-dimensional evaluation of neurovascular anatomy, as injury to the inferior alveolar nerve or mental nerve can result in postoperative paraesthesia or dysesthesia. Studies have shown that panoramic radiographs may underestimate canal position and cannot reliably demonstrate the anterior loop, making CBCT an important tool when implants are planned in posterior mandibular regions.<sup>10-13</sup>

The presence of a bifid mandibular canal in 6% of cases, though less frequent, is still clinically significant because accessory canals may increase the risk of unexpected bleeding or nerve-related complications if not identified preoperatively.<sup>14</sup>

In the maxilla, sinus proximity (<2 mm) was observed in 24% of cases and sinus septa were present in 12%. These findings explain why sinus-related limitations were strongly associated with maxillary implant planning in our study. The posterior maxilla often presents reduced bone height due to sinus pneumatization, and CBCT images helps in identifying the available residual bone height and internal sinus anatomy. Detection of sinus septa is also important because septa may increase the risk of membrane perforation during sinus lift procedures.<sup>15</sup>

Incisive foramen close to implant was present in 10%, was similar to the other studies done previously by different authors. In their study, the incisive foramen was positioned in a manner that could influence implant placement near the central incisor in 4% of the 84 cases examined. To avoid potential complications, careful evaluation of the morphology of the incisive foramen and

the surrounding bone is essential, along with accurate assessment of the distance between the proposed implant site and adjacent anatomical landmarks.<sup>16, 17</sup>

An important outcome of our study was that CBCT led to at least one treatment plan modification in 66% of patients. The most common changes were modification of implant length (28%), diameter (22%), and angulation (18%), along with bone grafting (20%) and sinus lift planning (12%). This reflects the practical impact of CBCT in real clinical settings, where three-dimensional findings frequently influence the final surgical plan. Similar trends have been reported by other authors, where CBCT images altered implant planning by improving assessment of bone volume and the relationship with vital structures.<sup>18-22</sup>

## CONCLUSION

Overall, our findings support the clinical value of CBCT images for identifying anatomical constraints that may not be obvious on two-dimensional imaging. The use of CBCT can help reduce complications by allowing safer implant positioning and better selection of implant dimensions. However, CBCT should still be used judiciously, following radiation safety principles and selecting the smallest appropriate field of view.

## ACKNOWLEDGEMENTS – None

## REFERENCES

- Jacobs R. Dental cone beam computed tomography in implant dentistry: Recommendations for clinical use. *BMC Oral Health*. 2018;18:88. DOI: 10.1186/s12903-018-0523-5.
- Naitoh M, Hiraiwa Y, Aimiya H, Arij E. Observation of bifid mandibular canal using cone-beam computerized tomography. *International Journal of Oral & Maxillofacial Implants*. 2009;24(1):155-159.
- Orhan K, Aksoy S, Bilecenoglu B, Sakul BU, Paksoy CS. Evaluation of bifid mandibular canals with cone-beam computed tomography in a Turkish adult population: A retrospective study. *Surgical and Radiologic Anatomy*. 2011;33(6):501-507. DOI: 10.1007/s00276-010-0761-y.
- von Arx T, Friedli M, Sendi P, Lozanoff S, Bornstein MM. Location and dimensions of the mental foramen: A radiographic analysis using cone-beam computed tomography. *Journal of Endodontics*. 2013;39(12):1522-1528. DOI: 10.1016/j.joen.2013.07.033.
- Bornstein MM, Balsiger R, Sendi P, von Arx T. Morphology of the nasopalatine canal and the surrounding bone using cone-beam computed tomography: An evaluation of anatomical variations in implant patients. *Clinical Oral Implants Research*. 2011;22(6):639-645. DOI: 10.1111/j.1600-0501.2010.02075.x.
- Tadinada A, Fung K, Thacker S, Mahdian M. Role of cone beam computed tomography in implant dentistry: An update. *Journal of the California Dental Association*. 2015;43(12):711-718.
- Guerrero ME, Jacobs R, Loubele M, Schutyser F, Suetens P, van Steenberghe D. State-of-the-art on cone beam CT imaging

- for preoperative planning of implant placement. *Clinical Oral Investigations*. 2006;10(1):1-7. DOI: 10.1007/s00784-005-0029-1.
8. Bornstein MM, Scarfe WC, Vaughn VM, Jacobs R. Cone beam computed tomography in implant dentistry: A systematic review focusing on guidelines, indications, and radiation dose risks. *International Journal of Oral & Maxillofacial Implants*. 2014;29(Suppl):55-77. DOI: 10.11607/jomi.2014suppl.g1.4.
9. Al-Haj Husain A, Mergen V, Valdec S, Al-Haj Husain N, Stadlinger B, Essig H, Frauenfelder T, Kessler P, Lie SAN, Alkadhi H, Winklhofer S. Comparison of cone-beam computed tomography with photon-counting detector computed tomography for dental implant surgery. *International Journal of Implant Dentistry*. 2025;11(1):21. DOI: 10.1186/s40729-025-00591-8.
10. de Oliveira-Santos C, Souza PHC, de Azambuja Berti-Couto S, Stinkens L, Moyaert K, Rubira-Bullen IRF, et al. Assessment of variations of the mandibular canal through cone beam computed tomography. *Clinical Oral Investigations*. 2012;16(2):387-393. DOI: 10.1007/s00784-011-0525-y.
11. Vieira CL, Veloso SDAR, Lopes FF. Location of the course of the mandibular canal, anterior loop and accessory mental foramen through cone-beam computed tomography. *Surgical and Radiologic Anatomy*. 2018;40(12):1411-1417. DOI: 10.1007/s00276-018-2112-6.
12. Greenstein G, Cavallaro J, Tarnow D. Practical application of anatomy for the dental implant surgeon. *Journal of Periodontology*. 2008;79(10):1833-1846. DOI: 10.1902/jop.2008.080247.
13. Sghaireen MG, Srivastava KC, Shrivastava D, Ganji KK, Patil SR, Abuonq A, Mousa MA, Dar-Odeh N, Sghaireen GM, Kamal MA, Alam MK. A CBCT-based three-dimensional assessment of mandibular posterior region for evaluating the possibility of bypassing the inferior alveolar nerve while placing dental implants. *Diagnostics (Basel)*. 2020;10(6):406. DOI: 10.3390/diagnostics10060406.
14. Kuribayashi A, Watanabe H, Imaizumi A, Tantanapornkul W, Katakami K, Kurabayashi T. Bifid mandibular canals: Cone beam computed tomography evaluation. *Dentomaxillofacial Radiology*. 2010;39(4):235-239. DOI: 10.1259/dmfr/66254780.
15. Pommer B, Ulm C, Lorenzoni M, Palmer R, Watzek G, Zechner W. Prevalence, location and morphology of maxillary sinus septa: Systematic review and meta-analysis. *Journal of Clinical Periodontology*. 2012;39(8):769-773. DOI: 10.1111/j.1600-051X.2012.01897.x.
16. Kim YT, Lee JH, Jeong SN. Three-dimensional observations of the incisive foramen on cone-beam computed tomography image analysis. *Journal of Periodontal & Implant Science*. 2020;50(1):48-55. DOI: 10.5051/jpis.2020.50.1.48.
17. Kraut RA, Boyden DK. Location of incisive canal in relation to central incisor implants. *Implant Dentistry*. 1998;7(3):221-225. DOI: 10.1097/00008505-199807030-00010.
18. Dula K, Bornstein MM, Buser D, Dagassan-Berndt D, Ettlin DA, Filippi A, et al. SEDENTEXCT guidelines for CBCT in dental and maxillofacial radiology. *Dentomaxillofacial Radiology*. 2012;41(7):507-517.
19. European Commission. Radiation Protection No. 172: Cone Beam CT for Dental and Maxillofacial Radiology—Evidence-Based Guidelines. Luxembourg: Publications Office of the European Union; 2012.
20. Chung WYC, Wang F, Leung YY. CBCT assessment for dental implant surgery at the maxilla: A clinical update. *Diagnostics (Basel)*. 2026;16(3):479. DOI: 10.3390/diagnostics16030479.
21. Hussaini S, Glogauer M, Sheikh Z, Al-Waeli H. CBCT in dental implantology: A key tool for preventing peri-implantitis and enhancing patient outcomes. *Dentistry Journal (Basel)*. 2024;12(7):196. DOI: 10.3390/dj12070196.
22. Misch CE, Judy KW. Classification of partially edentulous arches for implant dentistry. *International Journal of Oral Implantology*. 1986;4:7-13.