Relationship between inferior wall of maxillary sinus and maxillary posterior teeth using cone-beam computed tomography in healthy and chronic periodontitis patients

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Abstract:
Background: For dental implant planning in maxillary posterior region, it is essential to know their relationship with maxillary sinus. Maxillary posterior teeth affected by chronic periodontitis usually have a poor prognosis, ultimately leading to tooth loss. Following tooth loss, significant bone resorption occurs resulting in compromised remaining bone support for dental implant placement. Aim: The study aims to determine the relationship between inferior wall of maxillary sinus and the root apices of maxillary posterior teeth. Materials and Methods: The study sample consisted of cone-beam computed tomography images of 150 patients. Vertical distance between inferior wall of maxillary sinus and root apices and furcation area of maxillary posterior teeth as well as crest of the edentulous ridge were measured in periodontally healthy individuals (Group 1), chronic periodontitis patients (Group 2), and in patients with edentulous maxillary posterior region (Group 3). The data were analyzed using one-way analysis of variance and Tukey’s test to compare mean distances between groups and molars. Results: There was a significant difference in mean distances between Group 1 (3.067 ± 1.600), Group 2 (1.602 ± 0.536) and Group 3 (1.279 ± 0.476) (P = 0.00001) and between mean distances of four sites (7.101, 0.932, 0.903, and 0.402 mm) (P ≤ 0.05). There was no significant difference in mean distances between the first and second molars (2.1469; 2.0996) (P = 0.787). Conclusion: For planning of dental implant placement in maxillary posterior region, the clinician should consider the vertical relationship between maxillary sinus floor and root apices of maxillary molars.

Key words: Cone beam computed tomography, dental implant, maxillary posterior teeth, periodontal disease

INTRODUCTION

Dental implants are one of the current treatment modalities for partial and complete edentulism. Advances in surgical procedures and biomaterials have led to a great expansion in dental implant treatment options.[1]

Patient evaluation and treatment planning are essential steps in implant treatment and affect the overall success of implant therapy.[2] The trained implantologist should assess physical, medical, as well as dental conditions along with the possible outcomes. Further, the dentist should assess the type of alveolar ridge, bone quality, and bone availability with the help of dental radiographs such as radiovisiography and cone-beam computed tomography (CBCT), as well as evaluation of soft tissue at the implant site and amount of occlusal force/stress factors on the future implant prosthesis. After clinical evaluation of the patient along with radiographic and model analysis, the dentist must decide the type of implant-supported prosthesis that can be provided to the patient.[3]

The alveolar bone level measurements vary significantly between conventional radiographs and digital imaging such as CBCT. It is the current imaging modality, especially for dental implant planning because of its high accuracy,

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high spatial resolution, three-dimensional view of the area of interest, and low radiation dose.

For dental implant planning, it is important to know the anatomical relationship between maxillary posterior teeth and the inferior wall of maxillary sinus. Before surgical procedures including dental implant therapy, it is important to determine the close approximation of maxillary molar root apices and the inferior wall of maxillary sinus, especially first and second molars. In addition, these root apices may project into the sinus and may be separated by sinus mucosa alone.

Most challenging area for dental implant therapy is maxillary posterior region. In chronic periodontitis, maxillary molars usually have a poor prognosis, ultimately leading to tooth loss. In a 22-year follow-up study by Hirschfeld and Wasserman, 31.4% of molars were lost compared to 4.9% of single-rooted teeth. Numerous studies have confirmed loss of maxillary molars due to periodontal disease as compared to premolars and incisors. Most frequently lost teeth are maxillary molars as compared to mandibular teeth. Previous studies have shown that at the age of 55–64 years, 18% retained all of their molars and 51% retained their anterior teeth. Clinical studies have shown that response to periodontal therapy in furcation involved molars is poor as compared to molars without furcation involvement resulting in increased risk of further attachment loss.

Following extraction, there is resorption of alveolar bone height of about 1–2 mm and alveolar bone width of about 4–5 mm. Significant amount of bone loss occurs within 1-year postextraction and is maximum during first 3 months postextraction. Therefore, preservation of alveolar bone immediately after tooth extraction has a substantial effect on the functional as well as aesthetic outcomes following prosthetic treatment.

In maxillary posterior region, vertical and horizontal resorption of alveolar bone occurs at the same rate postextraction followed by pneumatization of maxillary sinuses. Thus, limiting the vertical distance between the alveolar ridge and the floor of maxillary sinus. Advanced periodontal disease, following extraction and maxillary sinus pneumatization results in compromised remaining alveolar bone support for dental implant placement.

Adell et al, conducted a study on osseointegration of dental implants in edentulous jaw with a follow-up period of 15 years. He observed that 2.8% of total number of jaws returned to removable dentures and all cases were upper jaws. Problem was not only to achieve osseointegration of implant but also to maintain it in the long run. Studies have shown that there is increased cortical and trabecular bone stresses in the maxillary posterior region which was independent of implant design, diameter, and direction of load. From biomechanical perspective, evaluation of cortical bone in maxillary posterior region is essential for dental implant planning.

Hence, this study was undertaken to understand and assess the relevance of vertical relationship between the inferior wall of maxillary sinus and furcation area, root apices of the maxillary molars, and edentulous area postextraction using CBCT in implant dentistry.

MATERIALS AND METHODS

The CBCT images taken at a Private Oral and Maxillofacial Radiology Center from June 2016 to December 2016 were retrospectively examined. Individuals received dental CBCT scans (SIRONA XG 3D, GALAXIS V1.9, 482 mGycm2) for dental purposes mainly for implant planning. CBCT images were selected based on following criteria: Participants more than 30 years of age, presence of all maxillary posterior teeth with no evidence of bone loss, maxillary posterior teeth with advanced periodontal disease (more than 50% bone loss), edentulous maxillary posterior ridge (1 year postextraction), and no evident sinus pathologies such as sinusitis, cysts, or tumors. All included CBCTs were from participants who were between 32 and 65 years of age.

Dental CBCT images of maxillary first and second molars of patients in health, chronic periodontitis, and edentulous ridge 1-year postextraction (due to any cause) were taken into consideration. The study was designed into three groups:

- **Group 1: Healthy group**
- **Group 2: Chronic periodontitis group**
- **Group 3: Edentulous group.**

**Group 1**

CBCT images (n = 50) of 22 men and 28 women were selected. All maxillary posterior teeth were present in all the participants. Only first and second molars were considered.

Four measurements were taken:

- **Vertical distance between inferior wall of maxillary sinus and furcation area perpendicular to occlusal plane (FS) [Figure 1]**
- **Mesiobuccal root apex to inferior wall of maxillary sinus along the longitudinal axis of the root (MB) [Figure 2]**
- **Distobuccal root apex to inferior wall of maxillary sinus along the longitudinal axis of the root (DB) [Figure 3]**
- **Palatal root apex to inferior wall of maxillary sinus along the longitudinal axis of the root (P) [Figure 4].**

**Group 2**

CBCT images (n = 50) of 32 men and 18 women were selected. All maxillary posterior teeth with advanced periodontal disease were considered. Same measurements were taken as in group 1 [Figures 5-8].

**Group 3**

CBCT images (n = 50) of 24 men and 26 women were selected. Maxillary posterior teeth lost due to caries, trauma, or periodontal disease were considered. Vertical distance between inferior wall of maxillary sinus and crest of edentulous ridge in maxillary first and second molar region were measured [Figure 9].

The images were examined by trained oral and maxillofacial radiologist. All measurements were taken using built-in measurement tools. Intraobserver variation was determined by repeating all measurements at an interval of 1 week. No significant difference was found between the two measurements.
Statistical analysis
Statistical evaluation included calculation of means and standard deviation of all groups. To compare the three groups, a two-way analysis of variance (ANOVA) and Tukey’s test were used. In all analysis, a significance level of 0.05 was used. Statistical analysis was carried out using Statistical Package for the Social Sciences version 22 [IBM India ltd., Pune, Maharashtra, India].

RESULTS
The CBCT images of 500 teeth of 150 individuals (78 males, 72 females, aged 32–65 years; mean age 43.7 ± 7.149 years) were examined. Age and sex distribution are given in Tables 1 and 2. The CBCT images taken were of three groups:

- Healthy group: Group 1 (mean age 42.26 ± 7.003) male – 22 (44%); female – 28 (56%)
- Group 2
- Group 3

Figure 1: Vertical distance from furcation to sinus floor in Group 1

Figure 2: Mesiobuccal root tip to sinus floor in Group 1

Figure 3: Distobuccal root tip is in close relation to sinus floor in Group 1

Figure 4: Palatal root tip is in close relation to sinus floor in Group 1

Figure 5: Vertical distance from furcation area to sinus floor in Group 2

Figure 6: Mesiobuccal root tip to sinus floor in Group 2
• Chronic periodontitis group: Group 2 (mean age 43.78 ± 7.305) male – 32 (64%); female - 18 (36%)
• Edentulous group: Group 3 (mean age 45.14 ± 7.477) male – 24 (48%); female – 26 (52%).

Gender and age distribution did not show any significant difference between the groups. The measurements for maxillary molars of both sides were averaged because no significant differences were found between them.

The mean, standard deviation, minimum, and maximum values are shown in Tables 3 and 4. Figure 10 shows mean distances of three groups: Group 1 (3.067 ± 1.600), Group 2 (1.602 ± 0.536), and Group 3 (1.279 ± 0.476). Figure 11 shows mean distance for maxillary first and second molars of all three groups. For molars, the mean values were: first molar (2.147 ± 1.400) and second molar (2.099 ± 1.274).

The mean distance in Group 1 (3.067 ± 1.600) was greater than in Group 2 (1.602 ± 0.536) as shown in Figure 12. The mean distances of FS (7.101 ± 2.257) were greater as compared to MB (0.932 ± 1.569), DB (0.903 ± 1.514), and P (0.402 ± 1.069) as shown in Table 4 and Figure 13. The mean distance of first (2.1469) and second (2.0996) molars in Group 1 and Group 2 is shown in Figure 14.

A two-way ANOVA using generalized linear model was carried out to compare three groups and two molars for

**Table 1: Age distribution**

| Age | n   | Mean±SD       | Minimum | Maximum |
|-----|-----|---------------|---------|---------|
| Group 1 | 50  | 42.260±7.003  | 30.000  | 58.000  |
| Group 2 | 50  | 43.780±7.305  | 30.000  | 58.000  |
| Group 3 | 50  | 45.140±7.477  | 32.000  | 58.000  |

n – Total sample size for each group; SD – Standard deviation

**Table 2: Sex distribution**

| Gender | n   | Male (%) | Female (%) |
|--------|-----|----------|------------|
| Group 1 | 50  | 22 (44)  | 28 (56)    |
| Group 2 | 50  | 32 (64)  | 18 (36)    |
| Group 3 | 50  | 24 (48)  | 26 (52)    |

n – Total sample size for each group

**Table 3: Mean distance (using site averages)**

| Factors | Levels | n   | Mean±SD | Minimum | Maximum |
|---------|--------|-----|---------|---------|---------|
| Groups  | Group 1 | 200 | 3.067±1.600 | 0.675   | 9.625   |
|         | Group 2 | 200 | 1.602±0.536 | 0.500   | 3.675   |
|         | Group 3 | 100 | 1.279±0.476 | 0.200   | 2.900   |
| Molars  | First molar | 250 | 2.147±1.400 | 0.200   | 7.450   |
|         | Second molar | 250 | 2.099±1.274 | 0.200   | 9.625   |

n – Total sample size for each group; SD – Standard deviation

**Figure 7:** Distobuccal is in close relation to sinus floor in Group 2

**Figure 8:** Palatal root tip is in close relation to sinus floor in Group 2

**Figure 9:** Vertical distance from alveolar crest to sinus floor in Group 3

**Figure 10:** Mean distances for Group 1, Group 2, and Group 3
significance of difference in the mean distances. There was no significant difference in the mean distances between the molars ($F = 0.17, P = 0.787$). However, the differences in mean distances within the groups were highly significant ($F = 128.13, P = 0.00001$) [Table 5].

Tukey’s test was done for pair-wise comparison of the groups, and a significant difference in mean distances between the groups was seen. Group 1 had highest mean distance (3.067 mm) followed by group 2 (1.602 mm) and group 3 (1.279 mm) [Table 6].

Table 4: Mean distance by Group 1, Group 2, and sites

| Factors          | Levels                  | n  | Mean±SD               | Minimum | Maximum |
|------------------|-------------------------|----|-----------------------|---------|---------|
| Groups           | Group 1                 | 800| 3.067±3.353           | 0.000   | 14.300  |
|                  | Group 2                 | 800| 1.602±2.680           | 0.000   | 9.700   |
| Molars           | First molar             | 800| 2.373±3.248           | 0.000   | 13.700  |
|                  | Second molar            | 800| 2.296±3.192           | 0.000   | 14.300  |
| Sites            | FS                      | 400| 7.101±2.257           | 2.000   | 14.300  |
|                  | MB                      | 400| 0.932±1.569           | 0.000   | 9.300   |
|                  | DB                      | 400| 0.903±1.514           | 0.000   | 9.300   |
|                  | P                       | 400| 0.402±1.069           | 0.000   | 9.500   |

$n$ – Total sample; SD – Standard deviation; FS – Furcation to sinus floor; MB – Mesiobuccal root tip to sinus floor; DB – Distobuccal root tip to sinus floor; P – Palatal root tip to sinus floor

Highly significant differences in mean distances between the groups ($F = 401.11, P = 0.00001$) and no significant difference in mean distances was seen for molars ($F = 1.10, P = 0.295$). Differences in the mean distances for sites (FS, MB, DB, and P) were statistically highly significant ($F = 1898.95, P = 0.00001$) [Table 7].

Table 5: Factor and levels: Mean distances (using site averages)

| Factor          | Type    | Levels                  | Values             |
|-----------------|---------|-------------------------|--------------------|
| Groups          | Fixed   | 3                       | Group 1            |
|                 |         |                         | Group 2            |
|                 |         |                         | Group 3            |
| Molars          | Fixed   | 2                       | First molar        |
|                 |         |                         | Second molar       |

ANOVA

| Source          | df | SS   | MS    | $F$  | $P$  |
|-----------------|----|------|-------|------|------|
| Groups**        | 2  | 303.60 | 151.80 | 128.13 | 0.00001 |
| Molars          | 1  | 0.28  | 0.28  | 0.17  | 0.787 |
| Groups × molars | 2  | 3.375 | 1.688 | 1.42  | 0.242 |
| Error           | 494 | 585.253 | 1.688 |       |      |
| Total           | 499 | 892.515 |      |       |      |

**$P$ ≤ 0.05 is significant. df – Degree of freedom; SS – Sum of square; MS – Mean square; ANOVA – Analysis of variance; $F$ – Ratio of mean square; $P$ – Level of significance
The differences in the mean distances were highly significant within each group. The site FS had the highest mean distance (7.101 mm) followed by MB, DB and P (0.932, 0.903 and 0.402) [Table 8].

**DISCUSSION**

In the present study, the vertical relationship between inferior wall of maxillary sinus and furcation area, root apices of maxillary molars, and edentulous region postextraction were evaluated using CBCT images. For planning of dental implant in maxillary posterior region, clinicians must be aware of close approximation of maxillary molar roots to maxillary sinus because of its clinical relevance in surgical procedures and in implant dentistry. It has been observed that maxillary molars are in close association with maxillary sinus floor. Studies have shown that the incidence of this association varies between second molars (45.5%), first molars (30.4%), and second premolars (19.7%).

In the present study, the average distance between the maxillary molar furcation area and the inferior wall of maxillary sinus was 7.101 mm. Didilescu et al. evaluated the sinus floor-furcation topography based on vertical relationships of each maxillary molar root apices to sinus floor and observed that the average values were 7.64, 9.69, and 12.41 mm.

The mean distance between maxillary molar root apices and the inferior wall of maxillary sinus was least for palatal root (0.402 mm) as compared to mesiobuccal (0.932 mm) and distobuccal root apices (0.903 mm). It was observed that all maxillary molar roots mainly palatal root was in close approximation to the inferior wall of maxillary sinus. Similarly, Didilescu et al. in a study observed that the palatal root of the maxillary first molar had the closest relationship with the sinus floor and was the predictor for furcation-sinus floor distance. They concluded that furcation-sinus floor distance is an important consideration for dental implant therapy. Conversely, Kwak et al. and Kilic et al. observed that distobuccal root apex of maxillary second molar was close to the sinus floor. Eberhardt et al. and Georgescu et al. reported that the mesiobuccal root apex of maxillary second molar was close to the sinus floor.

The maxillary posterior teeth affected by periodontal disease usually have a poor prognosis as compared to other teeth. Maxillary molars with furcation involvement have a high risk of tooth loss which may lead to inferior expansion of the sinus and inadequate remaining bone support. Buccal furcation of maxillary molars is commonly affected by periodontal disease as compared to mesial and distal furcation. In patients above 30 years with advanced periodontal disease, one of the furcation of maxillary molars is usually involved. Maxillary molars with grade 3 furcation involvement are usually considered for extraction, whereas treatment for maxillary molars with grade 1 and grade 2 furcation involvement is complex and may be considered for extraction. McFall et al. reported that maxillary molars with furcation involvement had greater periodontal attachment loss as compared to those without furcation involvement during the maintenance period.

Table 6: Tukey’s test (pair-wise comparison of groups)

| Groups | Group 1 | Group 2 | t    | P    |
|--------|---------|---------|------|------|
| Group 2 | 13.46   | 0.00001 | 2.42 | 0.0408 |
| Group 3 | 13.41   | 0.00001 | 2.42 | 0.0408 |

P = Level of significance; t = Tukey’s statistic for paired comparison

Table 7: Factor and levels: Mean distance

| Factor | Type | Levels | Values |
|--------|------|--------|--------|
| Groups | Fixed | 2      | Group 1, Group 2 |
| Molars | Fixed | 2      | First molar, Second molar |
| Sites  | Fixed | 4      | FS, MB, DB, P |

ANOVA

| Source          | df | SS  | MS   | F    | P    |
|-----------------|----|-----|------|------|------|
| Groups          | 1  | 588.05 | 588.05 | 401.11 | 0.00001 |
| Molars          | 1  | 2.35  | 2.35  | 1.10  | 0.2950 |
| Sites           | 1  | 12.186.60 | 4062.20 | 1898.95 | 0.00001 |
| Groups x Molars | 3  | 105.70 | 35.25  | 16.47  | 0.0001 |
| Groups x Sites  | 3  | 9.07   | 3.02   | 1.41   | 0.2370 |
| Groups x Molars x Sites | 3 | 12.11 | 4.04 | 1.89 | 0.1300 |
| Error           | 1584 | 3388.47 | 2.14  |
| Total           | 1599 | 16,574.13 |

1 P ≤ 0.05 is significant. df = Degree of freedom; SS = Sum of square; MS = Mean square; F = Ratio of mean square; P = Level of significance

Table 8: Tukey’s test (pair-wise comparison of sites)

| Sites | FS   | MB   | DB   |
|-------|------|------|------|
|       | t    | P    | t    | P    | t    | P    |
| MB    | 59.64 | 0.00001 | 12.11 | 4.04 | 1.89 | 0.1300 |
| DB    | 59.93 | 0.00001 | 0.0285 | 0.992 | 5.13 | 0.00001 |
| P     | 64.77 | 0.00001 | 4.844 | 0.00001 |

*P ≤ 0.05 is significant. FS – Furcation to sinus floor; MB – Mesiobuccal root tip to sinus floor; DB – Distobuccal root tip to sinus floor; P – Palatal root tip to sinus floor; t = Tukey’s statistic for paired comparison

In the present study, mean alveolar ridge height (distance between crest of alveolar ridge and floor of maxillary sinus 1-year postextraction) varied between 2.9 mm and 0.2 mm. This suggests that long-term edentulism leads to bone resorption and expansion of sinus resulting in a thin cortical bone separating the antrum from the oral cavity. Ulm et al. observed that the mean alveolar ridge height varied between 9.30 and 3.23 mm. Sharan et al. used panoramic radiographs to determine sinus floor changes and observed that extracted site showed an inferior expansion of maxillary sinus floor when compared to contralateral dentate site. Conversely, Nimigean et al. established three subantral classes (SAC 1–3) for the subantral residual bone, depending on the osseous height and the age of the edentulism. About 56% of cases had bone height of about 10 mm (SAC 1), 32% of cases had bone height of 5–10 mm (SAC 2), and 12% of cases had 2.5–5 mm (SAC 3).
Results obtained from the present study showed that height of the remaining alveolar bone is an important consideration in dental implant therapy.

For planning of dental implants, relationship between the inferior wall of the maxillary sinus and maxillary posterior teeth should be taken into consideration. This study also had limitations such as lack of clinical correlation, sample size, and CBCT images were evaluated by single examiner.

Within the limitations of this study, following conclusions were reached:

- Close proximity of maxillary second molars to the sinus floor
- Close proximity of palatal root tip to the sinus floor
- Decreased remaining bone height in maxillary molar region with periodontitis
- Compromised remaining bone level in maxillary molar region 1-year postextraction.

Preserving as much bone height as possible in maxillary molars affected by periodontal disease should be considered by immediate implant placement if sufficient bone height is available or sinus augmentation procedure should be done at the time of extraction followed by dental implant placement at later stage. Thus, three-dimensional architecture of thin sinus floor at the site of extraction will be maintained till the socket heals completely.

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Conflicts of interest
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