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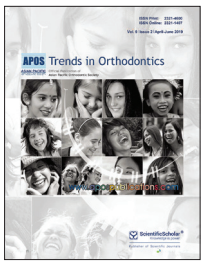

Original Article

Quantitative assessment of ramal bone width and the proximity of the inferior canal for the predictable insertion of ramal implants: Cone-beam computed tomography study

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ABSTRACT

Objectives: The study aimed to investigate the optimum level for the placement of ramal implants as a source of anchorage for disimpacting mandibular molars. The criteria in relation to the maximum transverse width of the ramal bone and proximity of the implant to the inferior alveolar canal (IAC) were evaluated using a three-dimensional cone-beam computed tomography scan for predictable placement of ramal implants.

Material and Methods: The cone-beam computed tomographic scans of 53 untreated patients (aged between 18 and 48 years) were utilized in this study. The maximum transverse width of the ramus and the proximity to the IAC from the site of insertion were measured at six different levels above the central groove of the mandibular first molar. To measure the proximity to the IAC, the mid-point of the maximum transverse width of the ramus was selected as the site of insertion of the implant.

Results: The maximum and minimum transverse ramal width was 12.48 ± 1.76 mm at 3 mm and 10.42 ± 2.08 mm at 8 mm above the central groove of the permanent mandibular first molar. An average clearance of 9.62 ± 2.59 mm was measured from the site of insertion to the IAC at the different levels evaluated.

Conclusion: The ramus of the mandible can be a predictable site for implant placement provided the variations in the anatomical structures have been carefully analyzed. It can be concluded that the ramal implants can be safely placed at a level 3–8 mm above the permanent mandibular first molar in relation to the occlusal plane.

Keywords: Orthodontics, Inferior alveolar nerve, Orthodontic anchorage, Temporary anchorage devices, Mandibular ramus

INTRODUCTION

Today's orthodontics is a mash-up of new and revised concepts, procedures, techniques, and evolving ideologies. Many advancements in treatment mechanics and diagnostic procedures have contributed to the expansion of orthodontic treatment options. Advances in skeletal anchorage and associated biomechanics have provided operators with novel ways to overcome major obstacles in orthodontic mechanotherapy. Temporary anchorage devices (TADs) have enabled previously unthinkable treatment outcomes a reality. Skeletal anchorage is based on the concept that undesirable reactive side effects of orthodontic tooth movements can be eliminated if skeletal structures can absorb these reactive forces, thereby achieving the desired therapeutic goals.

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The mandibular and maxillary third molars have the highest relative incidence of impaction, followed by the maxillary canines and mandibular bicuspids.[1] Impaction among mandibular second molars is uncommon. The prevalence of this was found to be 0.03% in the general population and 2.3% in orthodontic patients.[2,3] Unilateral impaction of the mandibular second molar is more common in males, with a clear preference for the right side.[4] The etiology of impaction could be attributed to factors such as an ectopic position that could have hampered the path of eruption and/or a failure in the mechanism of eruption.[5-9]

The management of such impacted teeth is exceptionally difficult for the orthodontist. In the treatment planning phase, the decision to extract or upright an impacted mandibular molar tooth presents a quandary. Several authors[10-18] have proposed various techniques for uprighting impacted mandibular molars. Kanomi[19] and other authors[20-23] have presented techniques for uprighting impacted mandibular molars using titanium mini-screws placed between the roots of the mandibular teeth. These implants were effective at providing direct and indirect anchorage for space closure and opening, but they had a higher failure rate.[24] They were not designed to deal with complex issues such as horizontally impacted mandibular molars. These implants also hindered tooth movement, had increased the risk of mobility within the bone, and increased the risk of tooth root damage. Another effective strategy proposed to address this issue is the use of extra-alveolar skeletal anchorage devices to deliver appropriate forces to difficult intraoral sites.[5,17,25,26]

Chang *et al*.[5,25] developed a stainless-steel extra-alveolar bone screw with a diameter of 2 mm and a length of 14 mm that is suitable for placement in dense cortical bone sites such as the anterior border of the ramus. According to Chang *et al*.,[5,17,25] the anterior border of the ramus site of implant placement provides a more posterosuperior line of traction along the plane of impaction, which can provide an occlusal and distal force component to upright and unlock the impacted mandibular molar. The presence of vital neurovascular structures, the complex clinical anatomy of the ramus, the thick soft tissue at the site of insertion, and difficulties in clinically asserting the direction of insertion all pose challenges to utilizing this site for implant placement. Improper placement complications may cause unnecessary iatrogenic damage and may result in medico-legal consequences.[27-42]

Although ramal implants have been successfully inserted in a variety of clinical situations, there has always been concern about their safety due to variations concerning the position of the neurovascular structures, the anatomy of the ramus of the mandible and the optimum height from the occlusal plane from which the implant is inserted.[5,43-47] Therefore, this study was conducted to identify the optimum level for the placement of ramal extra-alveolar implants by considering the transverse bone width of the Ramus and the proximity of the inferior alveolar canal (IAC) to the site of insertion using 3-dimensional (3D) perspective.

MATERIAL AND METHODS

The protocol for the study was approved by the institutional scientific review board (SRB/SDC/ORTHO-1904/21/020). For this investigation, a retrospective study design was planned.

Cone-beam computed tomographic (CBCT) scans of patients treated for orthodontic complaints from 2019 to 2020 at the Department of Orthodontics were sourced from the records. The inclusion criteria used to select the CBCT scan for evaluation are as follows-

1. No cleft lip/palate or other craniofacial anomalies
2. No prosthesis, missing teeth, or extensive carious lesions
3. No diagnosed systemic diseases
4. No gross variations in the anatomical structures of the mandible (Unilateral Condylar Hyperplasia, Bifid mandibular condyles, etc.)
5. No gross variation in the mandibular occlusal plane.

After applying the inclusion criteria, 53 CBCT scans were selected to be evaluated in the study. The sample population was from the Dravidian race and included 32 males and 21 females between the ages of 18 and 48 years with the average age being 23.5 years.

The CBCT scans were obtained using a Carestream CS9600 unit (Carestream Health Inc., NY). The Imaging parameters of the scans were as follows:

- Exposure-120 KV, 5 mA
- Scan Time-24 s
- Voxel Size-300 μm
- Focal spot-300 μm.

The scan data was saved as digital imaging and communications in medicine (DICOM) format. The DICOM files were reconstructed into 3D images for recording measurements using CS 3D Imaging software (version 3.10, Carestream Health Inc., NY, USA).

To standardize the orientation of the 3D images, the mandibular occlusal plane connecting the mesiobuccal cusp tips of the mandibular first molars and the right mandibular central incisor tip was used as the horizontal reference plane (occlusal plane). The midsagittal plane for the scan was constructed using the crista Galli, Anterior Nasal Spine (ANS), and Opisthion.[48]

To evaluate the maximum transverse width of the ramal bone, in this study, the central groove of the mandibular first molar was chosen as the dental reference point. To identify the central groove, first, the location of the permanent right mandibular first molar was determined by adjusting

the sagittal plane slider on the CBCT scan, after which the axial plane slider was used to position the axial plane at the mandibular occlusal plane level, and finally, the coronal plane was positioned on the central groove of the mandibular molar. To evaluate the maximum transverse width of the ramal bone at six different levels (3 mm, 4 mm, 5 mm, 6 mm, 7 mm, and 8 mm) above the dental reference point. Measurements were recorded in the axial plane at these levels.

Another important factor that needs evaluation was the distance from the point of insertion of the ramal implant to the inferior alveolar nerve to avoid damage to the neurovascular bundle. In this study, the midpoint of the measured maximum transverse ramal width was selected as the reference point of insertion. The distance to the IAC was measured from the selected point of insertion at all the above-mentioned six levels and this measurement was recorded parallel to the occlusal line.[43] To avoid any variations between the right and left sides, The measurements were performed for both the right and left sides in all subjects [Figure 1].

Since a dental landmark could have variation due to malocclusions causing alterations in the occlusal plane, a skeletal reference point was also used as a comparative landmark to remove any disparity. In this study, the lingula being a stable anatomic landmark was taken as the skeletal reference point.[49,50] The axial plane was adjusted to identify the most protruding point of the lingula,[51,52] from which the maximum transverse width of the ramus was measured at six different levels (3 mm, 4 mm, 5 mm, 6 mm, 7 mm, and 8 mm). These measurements were performed on both the right and left sides [Figure 2].

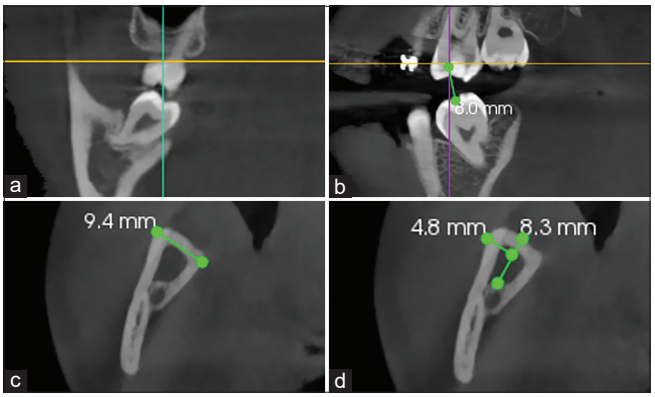

Figure 1: Procedures adopted in this study for recording the maximum transverse width of the ramus and its proximity to the inferior alveolar canal (IAC): In the coronal view, the slider (green line) is positioned on the central groove of the mandibular first molar (dental reference point), (a) On the sagittal view, a measurement of 8 mm is taken from the dental reference point perpendicular to the occlusal plane, (b) The axial plane is then positioned at that level (yellow line) (b) and the maximum transverse width of the ramus is measured on the axial plane, (c) The mid-point of the measured maximum transverse ramal width is measured on the same axial plane and is selected as the point of insertion of the ramal implant and the distance to the IAC is measured from this point (d).

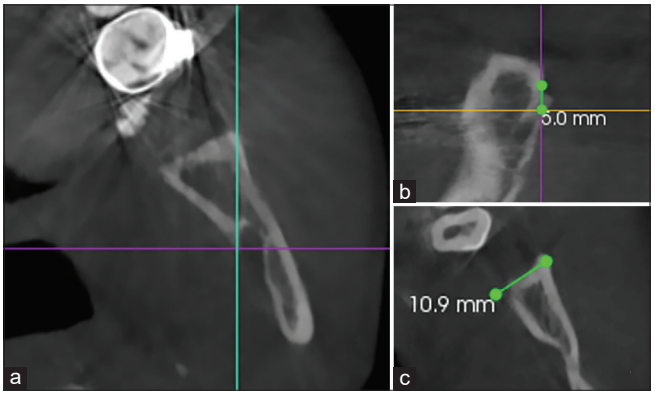

Figure 2: Procedures adopted to localize the most protruding point of the lingula: On the axial view of the cone-beam computed tomographic, the most protruding point of the lingula (skeletal reference point) is identified (intersection of the green and purple lines), (a) On the sagittal plane, a measurement of 5 mm is taken above the skeletal reference point, (b) the axial slider is then positioned at that level and the maximum transverse width of the ramus is measured on the axial plane (c).

Statistical analysis

A preliminary analysis was performed on ten subjects to collect data to perform a power analysis evaluation. The transverse width of the ramal bone measured at 3 mm and 4 mm from the dental reference plane was used to estimate the power, as were the corresponding standard deviations. The power analysis revealed that to achieve an 85% power, the study required 48 subjects.

The statistical analyses for this study was performed using Statistical Package for the Social Sciences software (version 23.0, IBM Corporation, NY). The data was evaluated for normal distribution by using the Shapiro–Wilk test and Kolmogorov–Smirnov test. The tests indicated that the distribution of the obtained data was normal.

To avoid any discrepancy in the cases selected between the stable skeletal landmark (Lingula) and the selected dental landmark (central groove of the mandibular first molar), a paired *t*-test was performed to compare the difference in ramal width measured at the different levels at both the selected skeletal and dental reference points. This test ascertained that the scans selected showed no significant difference between the measurements taken ($P > 0.05$). Hence, it was ascertained that the dental landmark used as a reference point can be considered a stable landmark for all the 53 scans selected participants included in this study. The ramal width taken using the dental landmark was considered for further analysis.

A paired *t*-test was performed to compare the difference between the measurements taken on the right and left sides. This test showed no statistically significant difference between the measurements on both the right and left sides in all the evaluated CBCTs. Hence, the averaged values were used for further analyses.

Descriptive statistics and one-way analysis of variance (ANOVA) were used to compare the difference in width of the ramus and proximity to the IAC at the different levels. A Bonferroni's *post hoc* test was done when the ANOVA test identified a significant result. A Kendall Tau and Spearman Correlation test was conducted to determine a gender disparity in the measurements. The significant level was set at $p<0.05$ for the outcomes of the statistical analyses.

Intra-examiner reliability was estimated by repeating the outcome measurements for ten patients that were selected at random. Furthermore, ten patients were chosen at random and evaluated by a different operator to assess inter-examiner reliability. The methodologic error was estimated using paired *t*-tests and intraclass correlation coefficients for both inter- and intra-examiner reliability (ICC). There were no significant differences ($p<0.05$) between the two readings; all measurements were reliable, with the intra-examiner reliability ranging from 0.75 to 0.82 and the inter-examiner reliability ranging from 0.66 to 0.74.

RESULTS

The descriptive statistics indicated that the greatest transverse ramal width was 12.48 ± 1.76 mm, at 3 mm above the mandibular first molar [Table 1]. The descriptive statistics also highlighted the maximum clearance to the IAC from the selected site of insertion was 9.81 ± 2.64 mm, at the level of 3 mm above the mandibular first molar [Table 1]. The one-way ANOVA test identified a significant difference in the average ramal width measured at the different levels [Table 2]. The Bonferroni *post hoc* test highlighted those measurements taken at the level of 3 mm above the mandibular first molar, were significantly greater than the measurements taken at 6 mm (Mean Difference [MD] – 1.21 mm), 7 mm (MD – 1.57 mm), and 8 mm (MD – 2.02 mm) above the mandibular first molar. The *post hoc* test also showed that the measurements taken at 4 mm above the mandibular first molar were significantly greater than the measurements taken at 7 mm (MD – 1.20 mm), and 8 mm (MD – 1.65 mm) above the mandibular first molar [Table 2]. The ANOVA test did not identify a significant difference in the proximity to IAC measured at different levels [Table 2]. The Kendall Tau and Spearman correlation tests did not identify any gender disparity in the measurements ($p>0.05$).

DISCUSSION

Despite the relatively low incidence of impaction, the management of impacted mandibular second molars is relatively complex when compared to other more commonly impacted teeth and has been a challenge for the orthodontist.[53] Although numerous methods for recovering deeply impacted mandibular molars using both conventional and skeletal anchorage have been described in the literature,[20] these methods have varying degrees of success. The use of ramal implants to disimpact impacted mandibular second molars has proven to have a significant advantage over other conventional techniques because it offers the most suitable direction of traction to disimpact impacted mandibular second molars.[26]

Table 1: Descriptive statistics for the transverse width of the ramus and proximity to the IAC measured at different levels.

	At 3 mm	At 4 mm	At 5 mm	At 6 mm	At 7 mm	At 8 mm	Overall average
Transverse of the ramus (mm)	12.48±1.76	12.07±1.79	11.47±1.8	11.23±1.81	10.86±1.9	10.42±2.08	11.42±1.97
Proximity to the IAC (mm)	9.81±2.64	9.73±2.84	9.46±2.69	9.68±2.52	9.68±2.52	9.57±2.49	9.62±2.59

IAC: Inferior alveolar canal

Table 2: ANOVA and *post hoc* tests to the difference of transverse width of the ramus and proximity to the IAC measured at the different levels.

Statistical Test	Parameter	Significance
ANOVA	Transverse width of the ramal bone	0.000*
ANOVA	Proximity to the IAC	0.978
Post hoc (Bonferroni)	Transverse width of ramus at 3 mm versus at 6 mm	0.013*
Post hoc (Bonferroni)	Transverse width of ramus at 3 mm versus at 7 mm	0.000*
Post hoc (Bonferroni)	Transverse width of ramus at 3 mm versus at 8 mm	0.000*
Post hoc (Bonferroni)	Transverse width of ramus at 4 mm versus at 7 mm	0.015*
Post hoc (Bonferroni)	Transverse width of ramus at 4 mm versus at 8 mm	0.000*

ANOVA: Analysis of variance, IAC: Inferior alveolar canal. *Significant ($P<0.05$)

Although using the ramal bone as a site for TAD placement has biomechanical and efficiency benefits, it is underutilized due to anatomical and clinical challenges. These difficulties include thick soft tissue at the site of insertion, highly mobile alveolar mucosa, difficulty maintaining oral hygiene, soft-tissue hyperplasia, and complex anatomy of the ramus.[5,54-56] The use of a long-collared implant of 2 mm diameter and 14 mm length implant helps mitigate some of these challenges.[5,43]

According to Chang *et al*.,[5] a minimum of 14 mm implant length is recommended because the implant must clear the soft tissue by at least 5 mm for oral hygiene considerations, 5 mm length is required to penetrate the thick soft tissue, leaving only 3–4 mm of the implant to penetrate the bone.

In this study, two important biological factors for successful ramal implant placement were evaluated, the maximum transverse width of the anteromedial border of the Ramus at six different heights from the occlusal plane (3 mm, 4 mm, 5 mm, 6 mm, 7 mm, and 8 mm above the mandibular occlusal plane), and the proximity of the implant tip to the IAC at these different heights from the occlusal plane.

Results of our study indicated that the greatest average transverse width of the ramus identified was 12.48 ± 1.76 mm at a height of 3 mm above the mandibular first molar. From the measurements recorded in this investigation, it is clear that a ramal implant of 2 mm in diameter would have sufficient width of bone to anchor at all the six levels measured above the central groove of the permanent mandibular first molar (3 mm, 4 mm, 5 mm, 6 mm, 7 mm, and 8 mm). It is also been clinically evident that placing the implant at a higher level from the mandibular first molar gives the clinician more clearance to apply traction to disimpact the impacted mandibular second molar.

The second factor considered was to determine the distance from the tip of the implant to the IAC taking into consideration that 4 mm of the implant was inserted into the ramal bone.[5] From an operator's perspective, the iatrogenic damage due to the inferior alveolar neurovascular bundle penetration is of grave concern.[27-35] The results of our study show that the placement of ramal implants lies in the safe zone to the IAC when measured at 3 mm, 4 mm, 5 mm, 6 mm, 7 mm, and 8 mm above the permanent mandibular first molar. Our observations were made by considering the path of insertion of the ramal implant is parallel to the occlusal plane and the occlusal line. However, considering variations in the position of the IAC between subjects the authors recommend that operators use a CBCT scan to plan implant placement such that injury to the IAC can be prevented while placing ramal implants.[57] Some authors have recommended that angulating the implant 13–25° laterally from the occlusal line offers a greater clearance up to 7 mm from IAC thus reducing the odds of injury to the IAC.[43] However, further investigations are required to validate such observations.

The lingula was also utilized in this study as a stable anatomical reference[49-52] to compare and evaluate the use of the occlusal plane as a clinical reference and only the cases where there was no significant difference between the measurements of the skeletal and dental landmarks were used in this study.

One limitation of this study is that it does not account for the anatomical and morphological differences of the ramus in different skeletal and vertical facial patterns, and the sample size is insufficient to ideally ascertain any gender-based differences in ramus morphology.[36-42] Thus, the impact of these additional factors must be evaluated in future studies. Disimpaction of an impacted tooth should be attempted in all clinical situations unless certain factors dictate surgical removal. Furthermore, there is no substitute for the longevity and functional benefit of proprioception provided by natural dentition. As a result, before dismissing an impacted tooth as a lost cause, orthodontists must carefully consider and evaluate all options.

CONCLUSION

- Ramal implants can be safely placed between the level 3–8 mm above the central groove of the permanent mandibular first molar as the ideal reference point.
- There was a statistically significant difference between the width of the ramus at 3 mm, 4 mm, 6 mm, 7 mm, and 8 mm above the central groove of the permanent mandibular first molar, and the highest transverse width of the ramus was identified at the level of 3 mm above the central groove of the permanent mandibular molar.
- In relation to the proximity to the IAC, results show an average clearance of 5.62 mm for the implant tip to the IAC, indicating that ramal implants can be safely placed between 3 and 8 mm from the central groove of the permanent mandibular molar.
- Operators should carefully consider the anatomic and morphologic parameters before the placement of the ramal implants with due consideration of the soft-tissue thickness.

Declaration of patient consent

Permission for the study was obtained from the institutional scientific review board. Patient consent was obtained when the pre-treatment records were taken.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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