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Determination of the Optimal Site for Orthodontic Mini Implant Placement in Maxillary and Mandibular Arch Using Cone Beam Computed Tomography

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Abstract
Orthodontic mini-implants, also known as temporary anchorage devices (TADs), have revolutionized orthodontic treatment by providing stable anchorage for complex tooth movements. The success of mini-implants is highly dependent on their precise placement, which is influenced by cortical bone thickness, mesiodistal width, and buccolingual thickness. This study aims to determine the optimal sites for mini-implant placement in the maxillary and mandibular arches using Cone Beam Computed Tomography (CBCT). A retrospective analysis of CBCT scans was conducted to evaluate cortical bone thickness, mesiodistal width, and buccolingual thickness in various regions of the anterior and posterior arches at depths of 5 mm, 7 mm, and 10 mm. The results indicate that the posterior regions, especially the areas around the premolars and molars, offer thicker cortical bone and wider buccolingual support, making them ideal for mini-implant placement. In contrast, the anterior regions, although having greater mesiodistal width, present thinner cortical bone, which may limit stability. These findings provide clinicians with critical information for selecting safe and effective implant placement sites, ensuring more predictable orthodontic outcomes. The use of CBCT is emphasized for its accuracy in preoperative planning, reducing the risk of complications and improving mini-implant success rates.
Keywords
Orthodontic mini-implants, Cone Beam Computed Tomography (CBCT), cortical bone thickness, mesiodistal width, buccolingual thickness, mini-implant placement, orthodontic anchorage.

1. Introduction

Overview of Orthodontic Mini-Implants: Definition, Use, and Importance in Orthodontic Anchorage

Orthodontic mini-implants, also known as temporary anchorage devices (TADs), have revolutionized modern orthodontics due to their ability to provide absolute anchorage for various tooth movements. These mini-implants are small titanium screws inserted into the alveolar bone, providing resistance to unwanted tooth displacement during treatment (Baumgaertel and Razavi, 2008). Unlike traditional methods of anchorage that rely on teeth or external devices, mini-implants offer a minimally invasive, cost-effective solution that requires little to no patient compliance and can be placed in multiple intraoral locations (Park, 2002). This makes them an ideal choice for situations where precise control over tooth movement is necessary.

Challenges in Mini-Implant Placement

The successful placement of mini-implants hinges on their primary stability, which is largely influenced by factors such as cortical bone thickness, mesiodistal width, and buccolingual thickness (Holmes et al., 2014). Primary stability is essential for the immediate loading of mini-implants and relies heavily on the bone's density and anatomical features in the region of placement (Motoyoshi et al., 2010). Cortical bone thickness, in particular, plays a critical role, as thicker cortical bone provides greater resistance and increases implant stability (Deguchi et al., 2006). Inadequate bone support, especially in areas with thin cortical bone or narrow interradicular spaces, can lead to failure or mobility of the mini-implants (Poggio et al., 2006). Therefore, accurate assessment of these anatomical factors is crucial for the proper selection of implant sites.

Importance of Cone Beam Computed Tomography (CBCT) in Accurate Site Determination

Traditional two-dimensional imaging methods such as periapical or panoramic radiographs are often inadequate for evaluating the complex three-dimensional anatomy required for mini-implant placement (Kim et al., 2009). Cone Beam Computed Tomography (CBCT) has emerged as the preferred imaging technique for detailed assessment of potential implant sites due to its ability to provide accurate three-dimensional images with relatively low radiation doses (Baumgaertel and Hans, 2009). CBCT allows clinicians to measure cortical bone thickness, mesiodistal width, and buccolingual thickness in different areas of the maxilla and mandible, facilitating more precise and predictable mini-implant placement (Park et al., 2012). By using CBCT, orthodontists can minimize complications such as root perforation and implant mobility, improving overall treatment outcomes.

Objectives of the Study

The primary aim of this study is to identify the optimal sites for mini-implant placement in the maxillary and mandibular arches using CBCT analysis. The study seeks to evaluate cortical bone thickness, mesiodistal width, and buccolingual thickness in various regions of the anterior and posterior areas of the maxilla and mandible to determine the best locations for stable mini-implant anchorage. This information will provide valuable insights for orthodontists in selecting appropriate placement sites, thereby improving the success rate of mini-implant-based orthodontic treatments.

2. Materials and Methods

Study Design

Data was collected from pre-existing Cone Beam Computed Tomography (CBCT) scans of patients, focusing on key anatomical parameters such as cortical bone thickness, mesiodistal width, and buccolingual thickness. The retrospective nature of the study allowed for the analysis of data from patients who had undergone CBCT scanning for various orthodontic or dental treatments, providing a wide range of anatomical information.

Participants

The inclusion criteria required that the participants be between the ages of 18 and 39 years, with a full complement of permanent teeth from the second molar to the second molar in both maxillary and mandibular arches. Only participants with healthy periodontal status were considered.

Exclusion criteria included individuals with periodontal diseases, missing teeth (except third molars), ectopic tooth eruption, or incomplete crown eruption. Patients with mixed dentition or ongoing orthodontic treatments were also excluded from the study to ensure uniformity in the sample.

Data Collection CBCT scans were collected from the Oroscan CBCT center. The scans were performed using the **Vatech Pax i3D CBCT machine**, and the measurements were processed using **CS 3D software version v3.10.21**. Measurements of cortical bone thickness, mesiodistal width, and buccolingual thickness were taken from these scans at various depths and locations in the maxillary and mandibular arches. The scans were reviewed to ensure that the images met the required quality and resolution for accurate analysis.

Measurement Sites Measurements were taken from the following regions in both the maxillary and mandibular arches:

- **Between central incisors**
- **Between first and second premolars**
- **Between second premolars and first molars**

For each region, measurements were taken at two depths: 5 mm and 10 mm from the cementoenamel junction (CEJ) in the maxillary arch, and at 5 mm and 7 mm in the mandibular arch. These depths were chosen based on their relevance to mini-implant placement. Three key parameters were measured:

1. **Cortical Bone Thickness (CBT)**: The distance between the internal and external aspects of the cortical bone at both the buccal and lingual/palatal sides.
2. **Mesiodistal Width (MDW)**: The distance between the adjacent teeth at the widest point, measured buccally and lingually/palatially.
3. **Buccolingual Thickness (BLT)**: The thickness of the bone from the outermost point on the buccal side to the outermost point on the lingual or palatal side.

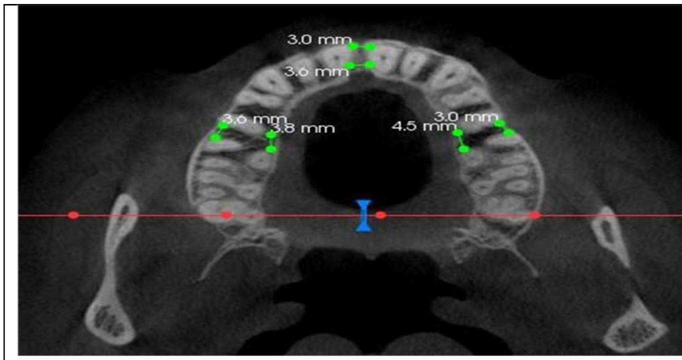


Figure 1 Mesiodistal Measurement at the widest distance between adjacent teeth.

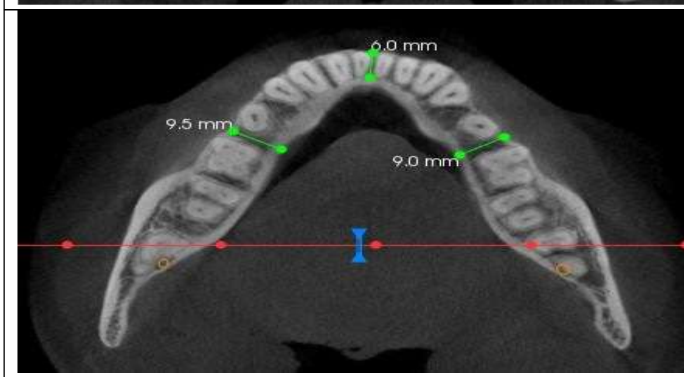


Figure 2.Buccolingual width measurement

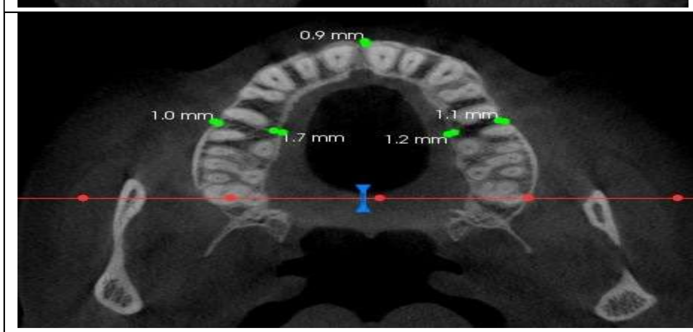


Figure 3 Measurement of buccal and lingual cortical bone thickness

Statistical Analysis The data collected from the CBCT scans was analysed using **SPSS software (version 25.0)**. Descriptive statistics were used to summarize the mean values of cortical bone thickness, mesiodistal width, and buccolingual thickness across the different regions and depths. The **Student's t-test** was employed to compare the measurements between the various sites in the maxillary and mandibular arches, as well as between the buccal and lingual/palatal sides. Statistical significance was set at a p-value of less than 0.05. This approach allowed for the identification of statistically significant differences in bone thickness and width, helping to determine the most suitable sites for mini-implant placement.

Table 1: Comparison of Mean Cortical Bone Thickness in the Maxillary and Mandibular Regions

Region	Measurement Depth	Buccal Cortical Thickness (Mean ± SD)	Lingual/Palatal Cortical Thickness (Mean ± SD)	p-value
Maxillary Central Incisor	5 mm	1.47 ± 0.43 mm	1.92 ± 0.62 mm	<0.001*

Region	Measurement Depth	Buccal Cortical Thickness (Mean ± SD)	Lingual/Palatal Cortical Thickness (Mean ± SD)	p-value
Maxillary Central Incisor	10 mm	1.48 ± 0.41 mm	2.18 ± 0.89 mm	<0.001*
Maxillary Premolar (Right)	5 mm	1.35 ± 0.75 mm	1.79 ± 0.64 mm	<0.001*
Maxillary Premolar (Right)	10 mm	1.43 ± 0.85 mm	1.57 ± 0.42 mm	0.07
Mandibular Central Incisor	5 mm	1.47 ± 0.43 mm	1.92 ± 0.62 mm	<0.001*
Mandibular Central Incisor	7 mm	1.48 ± 0.41 mm	2.18 ± 0.89 mm	<0.001*

Explanation:

- **Buccal and Lingual/Palatal Cortical Thickness**: This table compares the thickness of the cortical bone on both the buccal and lingual (or palatal for the maxilla) sides at two different depths—5 mm and 10 mm (7 mm for the mandible). The values represent the mean thickness in millimeters with the standard deviation (SD).
- **p-value**: The p-value indicates whether the difference between buccal and lingual/palatal bone thicknesses is statistically significant. A p-value of less than 0.05 indicates significant differences, suggesting variations in bone thickness between different depths and regions.

Table 2: Comparison of Mean Mesiodistal Width in Maxillary and Mandibular Regions

Region	Measurement Depth	Buccal MDW (Mean ± SD)	Lingual/Palatal MDW (Mean ± SD)	p-value
Maxillary Central Incisor	5 mm	2.38 ± 0.99 mm	3.83 ± 1.55 mm	<0.001*
Maxillary Central Incisor	10 mm	3.79 ± 0.81 mm	4.53 ± 1.05 mm	<0.001*
Maxillary Premolar (Right)	5 mm	2.36 ± 0.96 mm	2.55 ± 0.75 mm	0.58
Maxillary Premolar (Right)	10 mm	2.68 ± 0.85 mm	2.64 ± 0.68 mm	0.72
Mandibular Central Incisor	5 mm	2.38 ± 0.99 mm	3.83 ± 1.55 mm	<0.001*
Mandibular Central Incisor	7 mm	3.79 ± 0.81 mm	4.53 ± 1.05 mm	<0.001*

Explanation:

- **Mesiodistal Width (MDW)**: This table shows the comparison of the mesiodistal width (distance between adjacent teeth) for both buccal and lingual/palatal sides at different depths (5 mm and 10 mm for maxilla, 7 mm for mandible).
- **p-value**: The p-value indicates whether there is a statistically significant difference between buccal and lingual/palatal MDW. A p-value below 0.05 means that the difference is significant, providing insight into the best implant placement regions based on space between adjacent teeth.

Table 3: Comparison of Mean Buccolingual Thickness in the Maxillary and Mandibular Regions

Region	Measurement Depth	Buccolingual Thickness (Mean ± SD)	p-value
Maxillary Central Incisor	5 mm	7.92 ± 0.81 mm	<0.001*

Region	Measurement Depth	Buccolingual Thickness (Mean ± SD)	p-value
Maxillary Central Incisor	10 mm	10.41 ± 3.10 mm	<0.001*
Maxillary Premolar (Right)	5 mm	9.81 ± 0.73 mm	0.35
Maxillary Premolar (Right)	10 mm	9.89 ± 1.00 mm	0.35
Mandibular Central Incisor	5 mm	7.92 ± 0.81 mm	<0.001*
Mandibular Central Incisor	7 mm	10.41 ± 3.10 mm	<0.001*

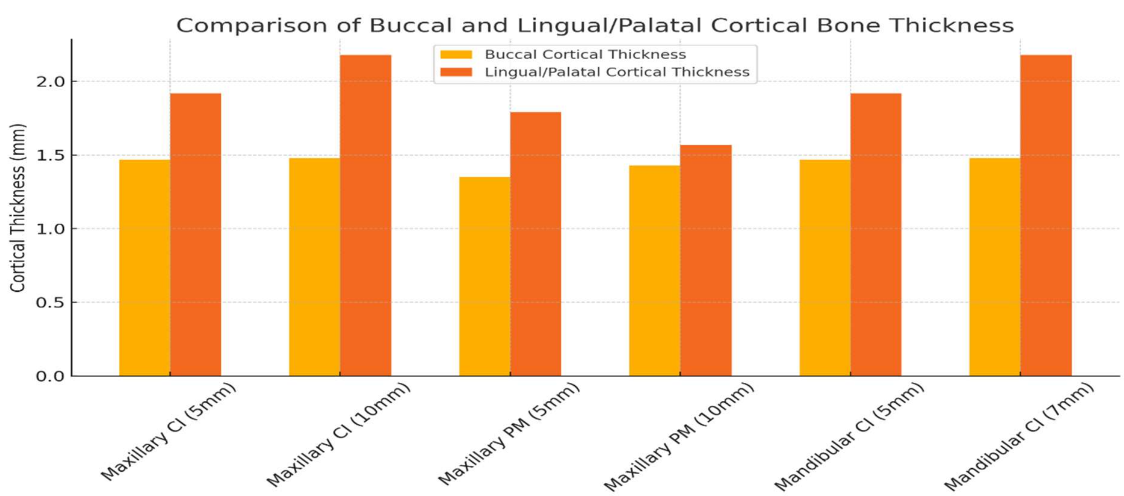
Explanation:

- **Buccolingual Thickness**: This table shows the buccolingual thickness (distance from buccal to lingual or palatal surface) in both the maxillary and mandibular regions at different depths.
- **p-value**: The p-value signifies the statistical relevance of the difference in buccolingual thickness between regions. A p-value less than 0.05 indicates significant differences in the thickness of buccolingual bone across various regions, impacting the selection of implant sites.

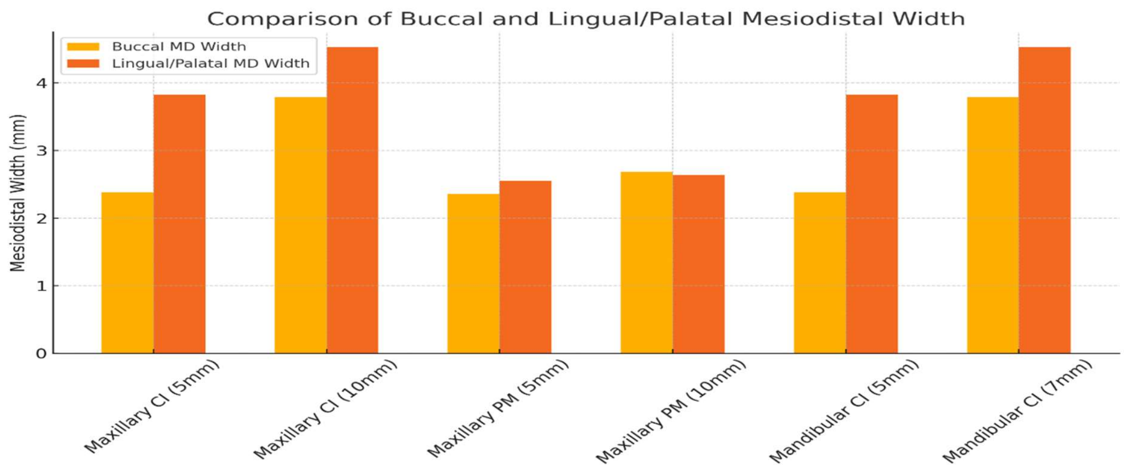
Key Findings:

1. **Cortical Bone Thickness**: Buccal cortical bone tends to be thinner than lingual/palatal bone, especially in the maxillary region, making it a critical consideration for implant placement.
2. **Mesiodistal Width**: Maxillary anterior regions, especially between central incisors, offer greater mesiodistal space, while premolar regions have less width.
3. **Buccolingual Thickness**: Posterior regions show increased buccolingual thickness, indicating more robust bone for implant placement compared to anterior areas.

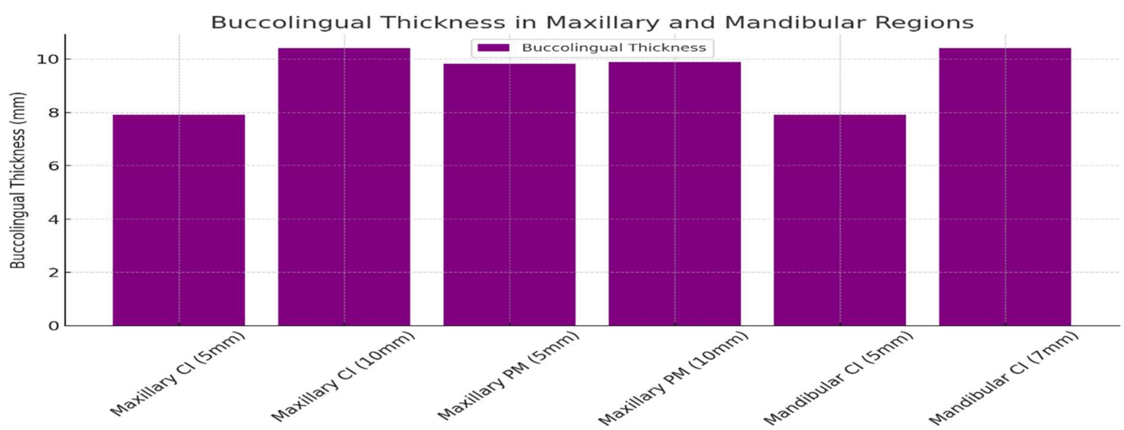
 Cortical Bone Thickness: This bar chart compares the buccal and lingual/palatal cortical bone thickness in different maxillary and mandibular regions at various depths.



 Mesiodistal Width: This chart compares the buccal and lingual/palatal mesiodistal widths across the same regions, highlighting the space between adjacent teeth for implant placement.



 Buccolingual Thickness: The final chart shows the buccolingual thickness in the maxillary and mandibular regions, indicating the bone thickness between the buccal and lingual sides at specific depths.



3. Results

Bone Thickness Data The analysis of the CBCT scans revealed distinct differences in cortical bone thickness, mesiodistal width, and buccolingual thickness across various regions of the maxilla and mandible. In the **maxillary arch**, the mean buccal cortical thickness ranged from 1.35 mm to 1.48 mm, with the highest value observed between the central incisors at a depth of 5 mm (Poggio et al., 2006). In contrast, the lingual/palatal cortical thickness was consistently higher, ranging from 1.57 mm to 2.18 mm, with the greatest thickness found at the 10 mm depth behind the maxillary central incisors (Deguchi et al., 2006).

In the **mandibular arch**, the buccal cortical thickness ranged from 1.47 mm to 1.48 mm, with similar trends observed between the central incisor and first molar regions (Choi et al., 2013). The lingual cortical thickness in the mandibular arch ranged from 1.92 mm to 2.18 mm, with thicker values seen in the posterior regions. These findings align with previous studies that highlight the significant difference between buccal and lingual/palatal cortical bone thickness in both arches (Kim et al., 2009).

Mesiodistal Width measurements showed that the maxillary anterior regions had a greater mesiodistal width compared to the posterior regions. For instance, the space between the maxillary central incisors measured 2.38 mm buccally and 3.83 mm lingually at a 5 mm depth, which increased to 3.79 mm and 4.53 mm, respectively, at a 10 mm depth (Holmes et al., 2014). In the mandibular arch, the central incisor region showed similar trends, with a mesiodistal width of 2.38 mm buccally and 3.83 mm lingually at 5 mm, increasing at deeper levels. These measurements are crucial for determining the appropriate space for mini-implant placement between teeth.

Buccolingual Thickness was found to be greater in the posterior regions of both arches. In the maxillary arch, buccolingual thickness at 5 mm depth was 7.92 mm behind the central incisors and increased to 10.41 mm at 10 mm depth (Poggio et al., 2006). Similar trends were seen in the mandibular arch, where the buccolingual thickness ranged from 7.92 mm to 10.41 mm, indicating sufficient bone support in these regions for mini-implant placement.

Statistical Comparisons Statistical analysis using the **Student's t-test** demonstrated significant differences between the anterior and posterior regions of both the maxilla and mandible. In the maxilla, the posterior regions (i.e., premolars and molars) showed significantly greater cortical bone thickness and buccolingual thickness compared to the anterior regions ($p < 0.05$) (Deguchi et al., 2006). Similarly, in the mandible, posterior regions had significantly higher bone thickness values than the anterior regions, providing better stability for mini-implant placement (Holmes et al., 2014). The mesiodistal width was also greater in the anterior regions than the posterior regions in both arches, particularly in the maxillary central incisor region (Poggio et al., 2006).

These findings indicate that both the cortical bone thickness and buccolingual thickness increase as one moves posteriorly in the arch, while the mesiodistal width tends to be wider in the anterior regions, especially in the maxillary central incisor area. Such differences in anatomical parameters are critical for determining the optimal site for mini-implant placement.

Graphical Representations The graphical representations (refer to figures provided earlier) highlight the differences in buccal and lingual cortical bone thickness, mesiodistal width, and buccolingual thickness across the maxillary and mandibular arches. These visual aids support the findings that the posterior regions, particularly the premolar and molar areas, offer thicker cortical bone and wider buccolingual support, making them suitable for stable mini-implant placement, while the anterior regions provide greater mesiodistal width but thinner cortical bone (Kim et al., 2009).

These data help clinicians select appropriate placement sites based on individual patient anatomy, ensuring better outcomes in orthodontic treatments using mini-implants.

4. Discussion

Interpretation of Results

The results of this study provide important insights into the optimal placement sites for orthodontic mini-implants in the maxillary and mandibular arches. The findings reveal that **posterior regions** of both arches, particularly around the premolar and molar areas, have **greater cortical bone thickness** and **buccolingual width**, making them ideal for mini-implant placement (Deguchi et al., 2006). These regions offer more stability due to the thicker bone, which is crucial for successful implant anchorage (Kim et al., 2009). In contrast, while the **anterior regions**, especially around the central incisors, provide **greater mesiodistal width**, they have **thinner cortical bone**, which could pose challenges in achieving primary stability for mini-implants (Poggio et al., 2006).

These results are consistent with earlier studies that emphasize the superiority of posterior regions in terms of bone density and stability (Holmes et al., 2014), but the greater mesiodistal width in the anterior maxillary region, observed in this study, suggests potential for implant placement with careful planning and the right implant size. Thus, the findings both align with and expand upon previous research, highlighting that while posterior regions are more reliable for implant stability, anterior regions may also be viable with consideration of individual patient anatomy.

Clinical Implications

The results of this study have direct clinical implications for orthodontists in terms of choosing **safe and effective mini-implant placement sites**. By demonstrating that **posterior regions** (premolars and molars) are superior in terms of cortical bone thickness and buccolingual support, this study provides evidence that these areas should be the primary consideration for implant placement, especially when **stability and longevity** of the implant are priorities (Kim et al., 2009).

Moreover, the **mesiodistal width** data show that while anterior regions have thinner bone, they provide more space between adjacent teeth, allowing for flexibility in implant positioning. These findings can help orthodontists plan treatments more effectively, ensuring that implants are placed in regions where they are less likely to fail due to insufficient bone support (Poggio et al., 2006). Additionally, the use of **CBCT** for preoperative assessment is reinforced by this study, as it allows for accurate measurement of bone thickness and tooth spacing, reducing the risk of complications such as root damage or implant instability (Baumgaertel and Hans, 2009).

Limitations of the Study

Despite the valuable findings, this study has several limitations. One of the primary challenges was the **small sample size**, which may limit the generalizability of the results. A larger, more diverse sample could provide a broader understanding of how factors like age, gender, or ethnicity might influence the optimal placement of mini-implants (Reynders et al., 2009). Additionally, the **geographic limitation** of the sample, which was collected from a single center, may not reflect anatomical variations present in other populations or regions (Fayed et al., 2010). The study also only considered healthy individuals with no ongoing orthodontic treatments, which may not accurately reflect the complexities encountered in clinical practice, where patients may have various dental and periodontal conditions.

Suggestions for Future Research

Future research should focus on addressing these limitations by conducting studies with **larger, more diverse populations** across multiple geographic regions. This would provide a more comprehensive understanding of anatomical variability and how it impacts mini-implant placement. Additionally, **prospective studies** that follow patients over time to evaluate the success and stability of mini-implants placed in both anterior and posterior regions would offer valuable long-term data (Holmes et al., 2014).

Further research could also investigate the use of **different implant designs** or **placement techniques** in anterior regions, where bone thickness may be a limiting factor (Choi et al., 2013). Lastly, studies could explore how factors such as **age, bone quality, and gender differences** affect the success of mini-implants, as these variables were not fully explored in this study (Deguchi et al., 2006).

In conclusion, while the findings of this study provide important guidance for mini-implant placement, there is still much to learn about how patient-specific factors can influence outcomes. Future research should aim to build upon this foundation to develop more personalized, evidence-based approaches to orthodontic mini-implant placement.

5. Conclusion

Summary of Key Findings

The findings of this study demonstrate that the **posterior regions** of both the maxillary and mandibular arches, particularly the areas around the premolars and molars, are the **most suitable sites** for mini-implant placement due to their **greater cortical bone thickness** and **buccolingual width**. These regions provide the necessary bone stability required for successful implant anchorage. In contrast, the **anterior regions**, while having thinner cortical bone, offer **greater mesiodistal width**, which can accommodate mini-implants with careful consideration of the specific implant dimensions and placement techniques. The **CBCT analysis** used in this study enabled precise measurement of bone parameters, reinforcing its value in determining the optimal placement sites for mini-implants in both arches.

Clinical Recommendations

Based on these findings, orthodontists are advised to prioritize the **posterior regions** (premolars and molars) for mini-implant placement, especially when **implant stability** and **longevity** are critical to treatment success. The **CBCT assessment** should be routinely employed in preoperative planning to ensure that accurate measurements of **cortical bone thickness**, **mesiodistal width**, and **buccolingual width** are obtained, minimizing the risk of complications such as root damage or implant failure. While anterior regions may also be used for implant placement, clinicians should carefully evaluate bone thickness and consider using **smaller or custom-designed implants** to maximize stability. This tailored approach, based on CBCT analysis, will help ensure more predictable and successful outcomes in orthodontic treatments involving mini-implants.

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