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COMPARATIVE ANALYSIS OF LINEAR MEASUREMENTS BETWEEN IMPACTED AND ERUPTED MANDIBULAR THIRD MOLARS USING DIGITAL PANORAMIC RADIOGRAPHS

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Abstract

Background: Despite the widespread use of panoramic radiographs for assessing third molars, there remains a need for a more thorough understanding of the precise linear measurements associated with impacted versus erupted mandibular third molars. Linear measurements provide objective, quantifiable data that can help differentiate between impacted and erupted third molars. These measurements may include the angular position of the tooth, the root length, the proximity to critical structures like the inferior alveolar nerve, and the distance to adjacent teeth or bone. Comparing these linear measurements between impacted and erupted third molars can help identify subtle anatomical differences that may not be apparent through clinical examination alone. **Material & Methods:** All participants were exposed to digital panoramic radiograph with SIRONA ORTHOPHOS XG using exposing parameters of 68kvp, 11m PmA, and 18 second/Carestream 8000C. Out of these participants 520 mandibular third molar teeth were assessed and were divided into two following 2 groups : Group A consisted of 260 erupted mandibular third molar teeth and Group B consisted of 260 impacted mandibular third molar teeth. Pattern of impaction of mandibular third molar teeth was categorized according to Winter's Classification into vertical, mesioangular, horizontal, distoangular, and others. **Results:** There is a significant difference in the mesiodistal width between impacted and erupted mandibular third molars. The impacted molars have a slightly larger MDW on average compared to erupted molars, with the difference being statistically significant. A significant difference is observed in the lower eruption space (LES-R) between impacted and erupted molars. Erupted molars have a larger average LES-R compared to impacted molars, indicating that less space is available in the impacted group, contributing to their impaction. Impact of Findings: The results indicate that erupted mandibular third molars generally have larger space measurements and higher space width ratios compared to impacted molars. These

differences are statistically significant and suggest that space availability is a crucial factor in the eruption of mandibular third molars. **Conclusion:** The findings suggest that specific linear measurements, such as the distance between the impacted third molar and the second molar, can serve as predictive indicators for impaction and potential complications. Understanding these measurements allows for more accurate early diagnosis and better preoperative planning, improving patient outcomes.

Keywords: Linear Measurements, Impacted, Erupted, Mandibular Third Molars, Radiographs

INTRODUCTION

Mandibular third molars, commonly known as wisdom teeth, are the last teeth to emerge in the human dentition, typically erupting during late adolescence or early adulthood. These teeth, however, are often subject to impaction—failure to fully emerge or align correctly within the dental arch. Impacted third molars are a frequent clinical concern in oral and maxillofacial practice due to their potential for pain, infection, cyst formation, and their association with dental crowding or misalignment of adjacent teeth. **1** Accurate diagnosis and evaluation of third molar impaction are essential for determining the appropriate treatment plan, which may involve extraction or monitoring for potential complications.

One of the most useful diagnostic tools for assessing mandibular third molar impaction is digital panoramic radiography, which provides a comprehensive view of the dental arch and surrounding anatomical structures. The panoramic radiograph offers several advantages over intraoral imaging, including a wide field of view, ease of patient positioning, and reduced radiation exposure compared to traditional full-mouth radiographs. **2** These benefits make it an invaluable tool in the evaluation of third molar eruption and impaction. The radiograph allows for the identification of various impaction types, including mesioangular, vertical, distoangular, and horizontal impactions, each associated with different degrees of difficulty in extraction and varying risks for complications. **3**

Despite the widespread use of panoramic radiographs for assessing third molars, there remains a need for a more thorough understanding of the precise linear measurements associated with impacted versus erupted mandibular third molars. Accurate radiographic measurements can provide insight into the spatial relationship between the molar and surrounding structures, as well as the degree of impaction. Several studies have attempted to quantify these relationships, but few have focused specifically on comparing the linear measurements of impacted and erupted third molars within the context of digital panoramic imaging. By exploring these differences, clinicians may be better equipped to predict the likelihood of impaction and make more informed decisions regarding treatment.

Impaction occurs when a tooth fails to emerge fully into its proper position in the dental arch. This can result from insufficient space, abnormal angulation, or obstruction by surrounding structures, such as the jawbone or adjacent teeth. Mandibular third molar impaction is particularly common, as these teeth are located at the rear of the dental arch, where space for eruption is often limited. Impaction can be categorized based on the angle of the tooth relative to the long axis of the second molar: vertical, mesioangular, distoangular, and horizontal. The degree of impaction, as well as the direction in which the tooth is positioned, affects the complexity of removal and the potential for postoperative complications. **4**

In addition to the position of the tooth, impaction may be classified according to its depth within the bone. This is often referred to as the "depth of impaction" and is classified into four types: soft tissue impaction, partial bony impaction, complete bony impaction, and completely impacted with no space for eruption **5** These classifications are important not only for predicting surgical difficulty but also for understanding the potential for pathological changes, such as the formation of pericoronal cysts or other dental infections. **6**

Digital panoramic radiographs are routinely used to assess the position, angulation, and relationship of the third molar to the surrounding anatomical structures, including the inferior alveolar nerve, the adjacent second molar, and the mandibular canal. The ability to visualize these relationships is crucial for preoperative planning, particularly when there is concern about the proximity of the third molar to the inferior alveolar nerve, which may complicate extraction . **1**

Panoramic radiography also offers valuable information about the size and development of the third molar, which can inform the likelihood of impaction. For example, measurements of the tooth's mesiodistal width, the length of the root, and the angle of eruption relative to the mandibular arch can provide important clues regarding the timing of eruption and potential impaction. Studies have shown that certain radiographic features, such as the angle of the third molar in relation to the second molar, may be predictive of impaction, with mesioangular impactions being most common. **3**

Additionally, linear measurements on panoramic radiographs, such as the distance between the crown of the impacted molar and the adjacent second molar or the distance from the molar to the lower border of the mandible, can provide more quantitative data that may predict the difficulty of extraction. Understanding the relationships between these measurements in impacted versus erupted molars could yield valuable information regarding the risk of complications and guide clinical decision-making.

Linear measurements provide objective, quantifiable data that can help differentiate between impacted and erupted third molars. These measurements may include the angular position of the tooth, the root length, the proximity to critical structures like the inferior alveolar nerve, and the distance to adjacent teeth or bone. Comparing these linear measurements between impacted and erupted third molars can help identify subtle anatomical differences that may not be apparent through clinical examination alone. **5** With this background, the study aims to determine the prediction and pattern of impacted mandibular third molar on a digital panoramic radiograph with the following objectives:

1. To evaluate the current pattern of third molar impaction on a digital panoramic radiograph and
2. To compare linear measurements between the impacted and erupted mandibular third molars on a digital panoramic radiograph.

MATERIAL & METHODS

STUDY DESIGN: Comparative cross-sectional study

STUDY AREA: The present study was conducted in the Department of Oral Medicine and Radiology, NIMS Dental College and Hospital, Jaipur and Rajasthan Dental College and Hospital, Jaipur, Rajasthan

STUDY PERIOD: 18 months

SELECTION CRITERIA OF PATIENTS: The study included 350 subjects selected by simple random sampling technique from the patients coming to the Department of Oral Medicine and Radiology of NIMS Dental College and Rajasthan Dental College.

INCLUSION CRITERIA:

1. Male and female Patients aged 18 to 40 years.
2. Those who were willing to give voluntary, written, informed consent

EXCLUSION CRITERIA:

1. Patients with a history of one or two missing teeth.
2. Patients have a history of orthodontic treatment and orthognathic surgery.
3. Patients with a history of mandibular first or second molars extraction.
4. Patients with pathologies associated with mandibular third molar.
5. Patients with any dentofacial anomalies.

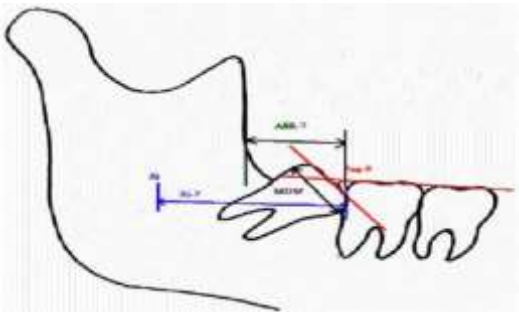
6. Patients with an abnormal mandibular third molar morphology.
7. Patients with a history of trauma to the mandible.
8. Pregnant females

METHODOLOGY:

- A total of 350 subjects were included who were willing to participate after written informed consent
- All participants were exposed to digital panoramic radiograph with SIRONA ORTHOPHOS XG using exposing parameters of 68kvp, 11m PmA, and 18 second/Carestream 8000C
- Out of these participants 520 mandibular third molar teeth were assessed and were divided into two following 2 groups
- Group A consisted of 260 erupted mandibular third molar teeth and Group B consisted of 260 impacted mandibular third molar teeth.
- Pattern of impaction of mandibular third molar teeth was categorized according to Winter's Classification into vertical, mesioangular, horizontal, distoangular, and others
- The linear measurements were carried out in digital panoramic radiograph directly in a computer Using SIDEX software /Carestream 8000C

The following indices were measured:

- **MDW -** Mesiodistal width of mandibular third molar at its greatest diameter. The distance between the points of the maximum convexities of the mesial and distal surface of the crown of the mandibular third molar was measured.
- **LES-R**-Lower eruption space was measured by a line drawn from the distal surface of the mandibular second molar to the anterior edge of the ramus, along the occlusal plane.
- **LES-Xi-**Lower eruption space was measured by a line drawn from the distal surface of the mandibular second molar to Rickett's Xipoint (center of the ramus).
- **RI** (Space width ratio 1) --- Ratio between LES-R/ MDW.
- **R2** (Space width ratio 2) --- Ratio between LES-Xi/MDW.



Technique: Radio imaging technique: Digital Orthopantomography (OPG)

Results:

Table 1: Frequency distribution of age of subjects

Age Interval	Impaction	Eruption
≤ 20	69 (26.54%)	19 (7.31%)
20 - 25	116 (44.62%)	118 (45.38%)
25 - 30	58 (22.31%)	69 (26.54%)

30 - 35	12 (4.62%)	30 (11.54%)
35 - 40	5 (1.92%)	24 (9.23%)
Total	260 (100%)	260 (100%)

Interpretation: The data shows that by the age of 35-40 years, the probability of encountering new impactions is minimal. Most third molars that were likely to erupt have already done so, and any remaining third molars are more likely to stay impacted.
The frequency distribution indicates that impaction of mandibular third molars is more common at a younger age, particularly in individuals under 25 years.The age group 20-25 years is identified as a key period for both impaction and eruption, suggesting that this is when the mandibular third molars are most active in their developmental and eruptive stages.As individuals age beyond 25 years, the incidence of impaction decreases significantly, while the likelihood of eruption increases, indicating a maturation process in the eruption pattern.By the age of 35-40 years, most mandibular third molars that were going to erupt have already done so, and new cases of impaction are rare.

Table 2: Frequency distribution of gender of subjects

Gender	Impaction	Eruption
Male	165 (63.46%)	197 (75.77%)
Female	95 (36.54%)	63 (24.23%)
Total	260 (100%)	260 (100%)

Interpretation: The findings suggest that female subjects are less likely to experience impaction compared to males. However, females also have a lower incidence of mandibular third molar eruption. This could indicate potential differences in the developmental patterns or timing of eruption between genders.

Table 3: Group wise distribution of subjects

Group	Impaction	Eruption
Unilateral	80 (30.77%)	17 (6.54%)
Bilateral	180 (69.23%)	243 (93.46%)
Total	260 (100%)	260 (100%)

Interpretation: Bilateral impaction is significantly more common than unilateral impaction, indicating that when mandibular third molars are impacted, both sides are often affected. The high frequency of bilateral eruption further supports the idea that if eruption occurs, it is likely to happen symmetrically on both sides.
Impaction Patterns: The data shows a clear predominance of bilateral impaction (69.23%) over unilateral impaction (30.77%). This suggests that mandibular third molar impaction often occurs on both sides of the jaw, possibly due to symmetrical anatomical or developmental factors. The lower

frequency of unilateral impaction indicates that when one side is impacted, there is a high chance that the other side is impacted as well.

Eruption Patterns: A striking contrast is observed in the eruption patterns, with bilateral eruption (93.46%) being much more common than unilateral eruption (6.54%). This suggests that when mandibular third molars erupt, they tend to do so on both sides rather than just one. The low incidence of unilateral eruption could imply that eruption is typically a bilateral process, possibly influenced by similar developmental conditions on both sides of the jaw.

Comparative Analysis: The comparison between impaction and eruption patterns highlights a significant finding: while bilateral involvement (whether impaction or eruption) is common, unilateral cases are relatively rare. This could reflect the influence of systemic or local factors that simultaneously affect both sides of the mandible during the development and eruption of third molars.

Table 4: Descriptive statistics of linear measurement of impaction group

Impaction	Minimum	Maximum	Median (IQR)	Mean ± SD
MDW (MM)	8.4	19.7	10.9 (10.4 - 11.5)	10.93 ± 1.06
LES-R (mm)	10.8	21.2	16.3 (15.1 - 17.7)	16.3 ± 2.13
LES-Xi (mm)	15.8	32.5	25.9 (24.6 - 27.43)	25.94 ± 2.49
R1	0.94	2.14	1.52 (1.36 - 1.67)	1.52 ± 0.23
R2	1.41	3.1	2.37 (2.21 - 2.55)	2.38 ± 0.27

- **Range:** The MDW ranges from 8.4 mm to 19.7 mm, indicating variability in the size of the mandibular third molars among impaction cases.
- **Median and IQR:** The median MDW of 10.9 mm with an interquartile range of 10.4 - 11.5 mm shows that the majority of impacted third molars have a mesiodistal width close to 11 mm, with relatively narrow variability.
- **Mean and SD:** The mean MDW of 10.93 mm with a standard deviation of 1.06 mm confirms that while the average size is slightly above 10 mm, there is some variability in the measurement, though it remains relatively consistent.
- **Median and IQR:** The median LES-R of 16.3 mm with an IQR of 15.1 - 17.7 mm shows that most impacted third molars have a relatively moderate amount of eruption space, suggesting that the space might be insufficient for proper eruption in many cases.
- **Mean and SD:** The mean LES-R of 16.3 mm with a standard deviation of 2.13 mm indicates moderate variability in the available eruption space, with some cases having more space than others.
- **Range:** LES-Xi ranges from 15.8 mm to 32.5 mm, showing substantial variability in the space measured from the distal surface of the mandibular second molar to the Xipoint.
- **Median and IQR:** The median LES-Xi of 25.9 mm with an IQR of 24.6 - 27.43 mm indicates that most impacted third molars have a relatively larger amount of space available when measured using the Xipoint method.
- **Mean and SD:** The mean LES-Xi of 25.94 mm with a standard deviation of 2.49 mm suggests significant variability in this measurement, with some cases having considerably more space than others.
- **Range:** R1 values range from 0.94 to 2.14, reflecting variability in the ratio of available space to the mesiodistal width of the third molar.

- **Median and IQR:** The median R1 of 1.52 with an IQR of 1.36 - 1.67 suggests that most impacted third molars have a space-to-width ratio around 1.5, which may be insufficient for proper eruption.
- **Mean and SD:** The mean R1 of 1.52 with a standard deviation of 0.23 indicates that while most values are close to 1.5, there is some degree of variability in this ratio among impacted molars.
- **Range:** R2 values range from 1.41 to 3.1, showing variability in the ratio of available space to the mesiodistal width of the third molar measured using the Xipoint method.
- **Median and IQR:** The median R2 of 2.37 with an IQR of 2.21 - 2.55 indicates that most impacted third molars have a space-to-width ratio greater than 2.0, suggesting that while there is space available, it might still be insufficient for proper eruption.
- **Mean and SD:** The mean R2 of 2.38 with a standard deviation of 0.27 reflects a generally adequate amount of space for many impacted molars, although variability exists.
- **MDW:** The mesiodistal width of impacted third molars shows moderate variability, with most measurements falling around 11 mm. This indicates that the size of the third molar may contribute to impaction if the available space is insufficient.
- **LES-R and LES-Xi:** Both measurements indicate that the available space for eruption is variable, with some cases having more space than others. However, the presence of impaction suggests that even with moderate to ample space, other factors may be influencing the impaction.
- **R1 and R2 Ratios:** Both R1 and R2 ratios suggest that space relative to the mesiodistal width is often inadequate for proper eruption, with a significant number of cases showing values that indicate potential insufficiency in space.

Table 5: Descriptive statistics of linear measurement of eruption group

Eruption	Minimum	Maximum	Median (IQR)	Mean ± SD
MDW (MM)	8.1	19.8	10.5 (9.9 , 11.2)	10.56 ± 1.2
LES-R (mm)	1.9	24.9	19.9 (18.6 , 20.93)	19.66 ± 2.41
LES-Xi (mm)	13.5	38.1	28.7 (27 , 30.6)	28.63 ± 3.35
R1	0.7	2.52	1.88 (1.73 , 2.01)	1.87 ± 0.25
R2	1.37	4.18	2.76 (2.48 , 2.97)	2.75 ± 0.374

- **Range:** The MDW ranges from 8.1 mm to 19.8 mm, reflecting variability in the size of the erupted mandibular third molars.
- **Median and IQR:** The median MDW of 10.5 mm with an interquartile range of 9.9 - 11.2 mm indicates that most erupted third molars have a mesiodistal width close to 10.5 mm, with limited variability.
- **Mean and SD:** The mean MDW of 10.56 mm with a standard deviation of 1.2 mm confirms that the average size of erupted molars is slightly above 10 mm, with modest variability around this mean value.
- **Range:** LES-R values range from 1.9 mm to 24.9 mm, demonstrating a broad range of available space for erupted mandibular third molars.
- **Median and IQR:** The median LES-R of 19.9 mm with an IQR of 18.6 - 20.93 mm indicates that most erupted third molars have a relatively larger amount of space, which is consistent with the eruption of these teeth.
- **Mean and SD:** The mean LES-R of 19.66 mm with a standard deviation of 2.41 mm shows that while the average space is adequate for eruption, there is some variability in the space available.
- **Interpretation:**
- **Range:** LES-Xi varies from 13.5 mm to 38.1 mm, indicating substantial variability in the space available when measured from the distal surface of the mandibular second molar to the Xipoint.
- **Median and IQR:** The median LES-Xi of 28.7 mm with an IQR of 27 - 30.6 mm suggests that the majority of erupted third molars have a considerable amount of space available.

- **Mean and SD:** The mean LES-Xi of 28.63 mm with a standard deviation of 3.35 mm reflects a larger average space compared to the impaction group, indicating that erupted molars generally have more space, with some variability.
- **Range:** R1 values range from 0.7 to 2.52, showing variability in the ratio of available space to the mesiodistal width of the third molar.
- **Median and IQR:** The median R1 of 1.88 with an IQR of 1.73 - 2.01 indicates that the majority of erupted third molars have a space-to-width ratio around 1.88, which is generally adequate for eruption.
- **Mean and SD:** The mean R1 of 1.87 with a standard deviation of 0.25 suggests that while the ratio is relatively consistent, there is some variability in the space-to-width ratio among erupted molars.
- **Range:** R2 values range from 1.37 to 4.18, indicating variability in the ratio of available space to the mesiodistal width of the third molar when measured using the Xipoint method.
- **Median and IQR:** The median R2 of 2.76 with an IQR of 2.48 - 2.97 suggests that most erupted third molars have a space-to-width ratio greater than 2.5, indicating sufficient space for proper eruption.
- **Mean and SD:** The mean R2 of 2.75 with a standard deviation of 0.374 reflects a generally adequate amount of space relative to the mesiodistal width, with some variability among subjects.
- **MDW:** The mesiodistal width of erupted third molars shows moderate variability, with most measurements close to 10.5 mm, indicating that the size of erupted molars is somewhat larger on average compared to those that are impacted.
- **LES-R and LES-Xi:** Both measurements indicate a generally sufficient amount of space for the eruption of mandibular third molars, with the eruption group having more available space compared to the impaction group.
- **R1 and R2 Ratios:** The space width ratios for erupted molars are higher on average than for impacted molars, suggesting that erupted molars typically have more adequate space relative to their size, reflecting successful eruption.

Table 6: Comparing different parameters between impaction and eruption by using t-test

Variables	Impaction	Eruption	t - test	P - Value	Significance
MDW (MM)	10.93 ± 1.06	10.56 ± 1.2	3.754	<0.001	All are statistically significant
LES-R (mm)	16.3 ± 2.13	19.66 ± 2.41	-16.88	< 0.001	
LES-Xi (mm)	25.94 ± 2.49	28.63 ± 3.35	-10.296	< 0.001	
R1	1.52 ± 0.23	1.87 ± 0.25	-16.62	< 0.001	
R2	2.38 ± 0.27	2.75 ± 0.374	-12.78	< 0.001	

- There is a significant difference in the mesiodistal width between impacted and erupted mandibular third molars. The impacted molars have a slightly larger MDW on average compared to erupted molars, with the difference being statistically significant.
- A significant difference is observed in the lower eruption space (LES-R) between impacted and erupted molars. Erupted molars have a larger average LES-R compared to impacted molars, indicating that less space is available in the impacted group, contributing to their impaction.
- The LES-Xi is significantly different between impacted and erupted third molars, with erupted molars having a larger space compared to impacted ones. This suggests that the larger space available at the Xipoint may facilitate eruption and reduce the likelihood of impaction.
- A significant difference in the R1 ratio is noted, with erupted molars having a higher ratio compared to impacted molars. This indicates that the space available relative to the mesiodistal width is more adequate for erupted molars, which contributes to their successful eruption.
- The R2 ratio also shows a significant difference, with erupted molars having a higher ratio compared to impacted molars. This suggests that the ratio of space to mesiodistal width measured from the Xipoint is more favorable for erupted molars, reflecting a more favorable space condition.

- **Statistical Significance:** All parameters tested show statistically significant differences between impacted and erupted mandibular third molars, with p-values less than 0.001.
- **Impact of Findings:** The results indicate that erupted mandibular third molars generally have larger space measurements and higher space width ratios compared to impacted molars. These differences are statistically significant and suggest that space availability is a crucial factor in the eruption of mandibular third molars.

DISCUSSION

The present study, titled "Comparative Analysis of Linear Measurements Between Impacted and Erupted Mandibular Third Molars Using Digital Panoramic Radiographs", provides valuable insight into the anatomical differences between impacted and erupted third molars using digital panoramic radiography. The study's primary objective was to compare linear measurements of impacted and erupted mandibular third molars, contributing to a better understanding of how tooth position and impaction may influence these measurements. Although the results of this study provide important preliminary data, several factors must be considered to contextualize the findings and guide future research.

Radiographic Accuracy and Limitations

One of the key strengths of the study lies in the use of digital panoramic radiographs, a commonly employed tool in dental practice. Panoramic radiographs offer a broad overview of the entire dentition, including the position of impacted and erupted molars, making them a convenient and efficient diagnostic tool (Tavitian et al., 2018). **7** However, the limitations of this imaging technique must be acknowledged. Panoramic radiographs inherently suffer from distortion due to the 2D nature of the image and the geometric projection of the dental structures (Morris et al., 2014). **8** The magnification effect that occurs with panoramic imaging can lead to inaccurate linear measurements, especially when the tooth is located in different planes of the X-ray arc (Hatcher & Stepovich, 1999). **9** This is particularly relevant when measuring impacted third molars, as the positioning of the tooth can introduce errors that skew measurements of tooth size, root length, or proximity to adjacent structures.

To mitigate the inherent distortion of panoramic radiographs, cone-beam computed tomography (CBCT) could be used in future studies. CBCT provides 3D imaging, enabling a more accurate assessment of the spatial relationship between impacted and erupted third molars, including depth, angulation, and the precise distance to the mandibular canal (Sekerci et al., 2010). **10** By combining panoramic radiographs and CBCT, clinicians and researchers could achieve a more accurate and comprehensive analysis of third molar anatomy.

Sample Size and Population

Another significant consideration is the sample size**.** While the study may have had a sufficient sample size for initial findings, larger cohort studies are recommended to increase the statistical power of the results. Small sample sizes can lead to type II errors (false negatives), meaning that true differences between impacted and erupted molars may be overlooked (Kirkwood & Sterne, 2003). **11** Moreover, the study’s sample might have been limited in terms of demographic diversity (e.g., age, gender, ethnicity), which affects the generalizability of the findings. Given that tooth eruption patterns and impaction rates may vary by demographic factors, such as age and ethnicity (Panyasantisuk et al., 2016), **12** future studies should aim to include a more diverse cohort to assess how these variables impact the linear measurements of third molars.

Observer Bias and Measurement Consistency

The potential for observer variability is another concern. The accuracy of linear measurements on panoramic radiographs can be affected by the observer's skill and experience. Even small discrepancies in the interpretation of radiographic landmarks, such as the crown or root apex, can

lead to errors in measurement. To minimize this, it is essential to implement standardized protocols for measurements and employ multiple trained observers to cross-check the results. Future studies should also perform inter- and intra-observer reliability tests to ensure that measurements are consistent across different observers and over time (Mickelson et al., 2016). **13**

Eruption Patterns and Impaction Variability

The study focused on comparing linear measurements of impacted versus erupted mandibular third molars. However, the term "impaction" encompasses a wide range of possible tooth positions. Impacted third molars may be classified according to their angulation, such as vertical**,** mesioangular**,** distoangular, and horizontal impaction (Pati et al., 2018). **14** Each type of impaction may exhibit unique anatomical characteristics, such as varying crown and root sizes, proximity to the mandibular canal, and the degree of angulation, all of which could influence the linear measurements. Therefore, a more detailed classification of impaction types should be incorporated into future studies to provide a clearer understanding of how these factors influence linear measurements.

Moreover, the age of the patient at the time of the panoramic radiograph should be considered when analyzing third molar eruption. Third molars typically begin to erupt around the age of 17–21 years and may continue to develop and change position into the late 20s (Mejia et al., 2011). **15** The presence of different stages of eruption and impaction across various age groups could lead to variability in the linear measurements observed, further emphasizing the need for age-stratified analysis in future studies.

Clinical Implications and Predictive Value

The clinical relevance of the findings is an important aspect to consider. One of the primary clinical applications of studying impacted third molars is in determining whether intervention, such as extraction, is necessary. The linear measurements of third molars, such as their proximity to adjacent teeth, the mandibular canal, or the degree of impaction, may help guide the decision-making process. For example, mesioangular impactions are often associated with increased risk of complications during extraction, such as damage to the inferior alveolar nerve (Choi et al., 2017). **16** Thus, accurate radiographic measurements could serve as predictive markers for complications, and integrating these findings into a clinical risk assessment model could improve patient outcomes. While linear measurements can be helpful in this regard, it is important to note that 3D factors, such as tooth angulation, depth of impaction, and root morphology, also play a critical role in determining the complexity of third molar extractions. Panoramic radiographs alone may not provide sufficient detail for these factors, and a more comprehensive evaluation using 3D imaging techniques could better inform the clinical management of impacted third molars (Bortoluzzi et al., 2017). **17**

Recommendations

1. **Use of Multiple Imaging Modalities:** To increase the accuracy of measurements and reduce the limitations of panoramic radiographs, future studies could incorporate additional imaging modalities, such as Cone Beam Computed Tomography (CBCT)**.** CBCT provides 3D imaging that could offer more precise and detailed information on the positioning, angulation, and root morphology of both impacted and erupted third molars.
2. **Increase Sample Size:** A larger sample size would help increase the statistical power of the study, improving the reliability of the results. It would also reduce the impact of potential biases, such as selection bias, and make the findings more generalizable to the wider population.
3. **Standardization of Measurement Techniques:** To minimize observer bias and improve measurement consistency, the study should employ standardized measurement protocols for all linear measurements, including clear guidelines for identifying key landmarks on the panoramic radiographs.

4. **Incorporate Additional Anatomical Variables:** Future studies could consider incorporating other important anatomical factors, such as tooth angulation**,** depth of impaction, and root morphology**,** into the analysis. These factors may contribute significantly to the eruption or impaction process, and understanding them alongside linear measurements could provide a more holistic view of third molar development.
5. **Consideration of Clinical Variables:** The study could be expanded to consider clinical factors that may influence the eruption and impaction of third molars. For instance, patient age**,** gender**,** systemic health conditions**, and** dental treatments (such as extractions or orthodontic interventions) could all play a role in molar eruption and should be taken into account when analyzing linear measurements.
6. **Inclusion of Both Erupted and Impacted Molars in Various Positions:** It would be beneficial for future studies to examine a broader spectrum of impaction types**,** including vertical, mesioangular, distoangular, and horizontal impactions. Each type of impaction may have unique linear measurements, and understanding these variations could improve clinical decision-making regarding third molar extractions or management.

Limitations

1. Cross-sectional Nature of the Study: This study uses a cross-sectional design, which provides a snapshot of the conditions at a single point in time. As a result, the data cannot establish causal relationships between the type of molar (impacted vs. erupted) and certain anatomical measurements.
2. Sample Size and Demographics: The study may have a limited sample size, which could affect the statistical power and generalizability of the findings.
3. Quality and Image Resolution: Variations in the quality of digital panoramic radiographs (such as resolution, contrast, and clarity) may impact the precision of the measurements. Images with poor resolution or unclear anatomical landmarks can lead to inaccuracies in measuring the linear distances between structures.
4. Single Radiographic Modality: Relying exclusively on panoramic radiographs for linear measurements may limit the study's findings. While panoramic radiographs provide a broad overview of the mandibular arch, they lack the ability to assess certain 3D details.
5. Limited Analysis of Other Anatomical Variables: The study focussed solely on linear measurements, neglecting other relevant anatomical factors that could influence the eruption or impaction of third molars, such as the angulation, depth, or root morphology. These factors might play a significant role in the clinical outcomes, yet they are not addressed in the current study.
6. Influence of Other Factors: The study may not account for other factors influencing molar eruption or impaction, such as genetics, systemic health conditions, or previous dental treatments. These factors could potentially confound the results or introduce biases into the comparisons of linear measurements.

CONCLUSION

This study highlights the importance of digital panoramic radiographs in the evaluation of mandibular third molars, particularly in distinguishing between impacted and erupted teeth based on linear measurements. By comparing key radiographic dimensions, such as the angulation, distance to adjacent teeth, and proximity to critical anatomical structures, we gain valuable insights into the patterns of impaction and eruption. The findings suggest that specific linear measurements, such as the distance between the impacted third molar and the second molar, can serve as predictive indicators for impaction and potential complications. Understanding these measurements allows for more accurate early diagnosis and better preoperative planning, improving patient outcomes. This comparative analysis also underscores the significance of using digital panoramic radiographs not only for detection but also for guiding clinical decisions related to the management of impacted third molars.

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