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RESEARCH ARTICLE

PANORAMIC RADIOGRAPHY IN ORTHODONTIC DECISION-MAKING: A FOCUS ON MANDIBULAR THIRD MOLAR IMPACTION

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Abstract

Background: Impaction is defined as the failure of complete eruption of a tooth into a normal functional position within normal time due to lack of space in the dental arch caused by obstruction by another tooth or development in an abnormal position. Radiographic imaging plays a pivotal role in the evaluation, diagnosis, and management planning of third molar impactions. It provides critical information regarding tooth position, angulation, proximity to vital structures, and surrounding bone quality.

Objective: Hence present study was conducted to evaluate the pattern of mandibular third molar impaction and also assess the predictive validity of different linear measurements between the impacted and erupted mandibular third molars on digital panoramic radiographs.

Method: A comparative cross-sectional study has included 350 subjects from the patients coming to the Department of Oral Medicine and Radiology of NIMS Dental College and Rajasthan Dental College.All participants were exposed to digital panoramic radiograph with SIRONA ORTHOPHOS XG using exposing parameters of 68kvp, 11m PmA, and 18 second/Carestream 8000C.

Results: This age group has a relatively high frequency of impaction, with 69 subjects, accounting for 26.54% of the total cases of impaction.The AUC for LES-R is 0.858, indicating a high level of accuracy in predicting mandibular third molar impaction. The p-value (< 0.001) confirms that the result is statistically significant, indicating LES-R is a reliable predictor of impaction.The AUC for LES-Xi is 0.746, which represents a moderate level of accuracy in predicting impaction. The p-value (< 0.001) indicatesstatistical significance, meaning LES-Xi is a useful predictor, though slightly less accurate compared to LES-R.LES-R at the cut-off level of 19.45 mm has moderate sensitivity, indicating that it correctly identifies 61.20% of the

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impacted molars.The high specificitymeans LES-R accurately identifies 91.08% of erupted molars, minimizing false positives.Overall, LES-R has a high diagnostic accuracy, suggesting it is a reliable tool for predicting impaction, with a better performance in confirming non-impacted cases.

Conclusion: Our study provides a comprehensive evaluation of the spatial and angular factors contributing to mandibular third molar impaction, utilizing a robust dataset of linear and angular measurementsby using digital panoramic radiographs.Ultimately, this research supports a more proactive approach to third molar management, aimed at preventing the complications associated with impaction.

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Introduction:-

Impaction is defined as the failure of complete eruption of a tooth into a normal functional position within normal time due to lack of space in the dental arch caused by obstruction by another tooth or development in an abnormal position. Third molars or wisdom teeth usually begin to erupt between ages 17 to 21 years. [1]

An impacted tooth is described as a tooth that cannot or will not erupt into its normal functioning positiontherefore, it is pathologic and requires treatment. [2]Local factors that are responsible for tooth impaction include mechanical obstruction by a cyst, tumor,and inadequate space in the dental arch resulting from micrognathia, premature exfoliation of deciduous teeth, and discrepancy in tooth arch size. In addition, genetic disorders, endocrine disturbances,and previous jaw irradiation are some of the systemic factors that are responsible for impacted teeth.[3]

The prevalence of third molar impaction ranges from 16.7 % to 68.6%. Mandibular third molars are the most frequently impacted teeth and are 1.9 times more common than impacted maxillary third molars.[4]The third molars are particularly susceptible to impaction because they are the last teeth to erupt in the oral cavity, usually between the ages of 17 and 25 years. Given their late eruption and common developmental issues, they are often unable to emerge fully due to limited space in the jaw, making them the most frequently impacted teeth.[5]Numerous studies have explored the potential differences in third molar impaction between males and females. Some research, such as studies conducted in Iraq, has found a strong correlation between third molar impaction and the patient's sex and age. However, other studies have not found significant differences in the impaction status between men and women.

Radiographic Assessment of Mandibular Third Molar Impaction [6]

Radiographic imaging plays a pivotal role in the evaluation, diagnosis, and management planning of third molar impactions. It provides critical information regarding tooth position, angulation, proximity to vital structures, and surrounding bone quality.

Panoramic Radiography

Panoramic radiographs are widely utilized due to their comprehensive visualization of the maxillofacial region, ease of acquisition, and relatively low radiation exposure. They enable clinicians to assess multiple parameters simultaneously, facilitating thorough evaluation.

Advantages

1. **Comprehensive View:** Provides a broad overview of both jaws, including teeth, bones, and adjacent structures.
2. **Non-Invasive and Efficient:** Quick imaging process with minimal discomfort to the patient.
3. **Measurement Capabilities:** Allows for precise linear and angular measurements crucial for predicting impaction and planning surgical interventions.

Limitations

1. **Distortion and Magnification:** May present image distortions affecting measurement accuracy; however, modern digital systems have improved this aspect.
2. **Overlap of Structures:** Superimposition can obscure details, necessitating supplementary imaging in some cases.

As mandibular third molars are the most frequently impacted teeth and are two times more common than impacted maxillary third molars. The close proximity of important anatomical structures with the impacted mandibular third molar makes it necessary to study the pattern and predict the eruption of the impacted mandibular third molar. Hence present study was conducted to evaluate the pattern of mandibular third molar impaction and also assess the predictive validity of different linear measurements between the impacted and erupted mandibular third molars on digital panoramic radiographs.

Aim & Objectives:-

1. To evaluate the current pattern of third molar impaction on a digital panoramic radiograph.
2. To assess the validity of panoramic measurements in early prediction of mandibular third molar impaction.

Material & Methods:-

Study Design

Comparative cross-sectional study.

Study Population:

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.

Methodology:-

Ethical clearance of NIMS University Rajasthan Jaipur and Rajasthan Dental College and Hospital Jaipur was taken before commencing the study.

Selection Criteria of Patients:

The study included 350 subjects 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, informedconsent

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

- All participants were exposed to digital panoramic radiograph with SIRONA ORTHOPHOS XG using exposing parameters of 68kvp, 11m PmA, and 18 second/Carestream 8000C. By using panoramic radiographs evaluation of following done:
  - Mandibular third molar position (angulation, depth, and space availability)
  - Root development and shape
  - Adjacent bone density
- Out of these participants, mandibular third molar teeth were assessed and were divided into two following 2 groups via 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

Variables

1. Independent Variables:
   - Panoramic measurements (linear and angular)
   - Patient demographics (age, sex)
2. Dependent Variables:
   - Impaction status (yes/no)
   - Orthodontic treatment duration and complexity
   - Surgical interventions (if necessary)

Sample size estimation:

A total of 514, patients from the Department of Oral Medicine and Radiology of NIMS Dental College and Rajasthan Dental College was included in the study. The sample size was planned according to popularity after consulting with a statistician. Sample calculating formula is as follows:

$$\text{Sample Size (n)} = \frac{(Z_{1-\alpha/2} + Z_{1-\beta})^2 * (\delta_1^2 + \delta_2^2)}{(\mu_1 - \mu_2)^2}$$

$$= \frac{(1.96 + 0.84)^2 * (1.29^2 + 1.3^2)}{(14.19 - 13.87)^2}$$

$$= 7.84 * \frac{[1.664 + 1.69]}{(0.32)^2}$$

= **256.8 = 257/ each group – Round figure-260 /each group**

= 514 total sample

$Z_{1-\alpha/2}$= 1.96: Inverse normal value at 5% level of significance

$Z_{1-\beta}$= 0.84. Inverse normal value at 80% power

$\delta_1$andδ_2: Standard deviation of MDW

$\mu_1$andμ_2 : Means of MDW

Statistical Analysis:

- Descriptive statistics for demographic and radiographic data
- Inferential statistics (e.g., chi-squared test, logistic regression) to evaluate relationships between radiographic findings and clinical outcomes

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%)**

Table 1 presents the frequency distribution of age among the study subjects, specifically comparing the occurrence of mandibular third molar impaction and eruption across different age intervals.

Age Group ≤ 20 Years:

Impaction: This age group has a relatively high frequency of impaction, with 69 subjects, accounting for 26.54% of the total cases of impaction.

Eruption: In contrast, only 19 subjects (7.31%) in this age group exhibited erupted mandibular third molars.

Interpretation: The data suggests that in individuals aged 20 years or younger, there is a higher tendency towards impaction rather than eruption of mandibular third molars.

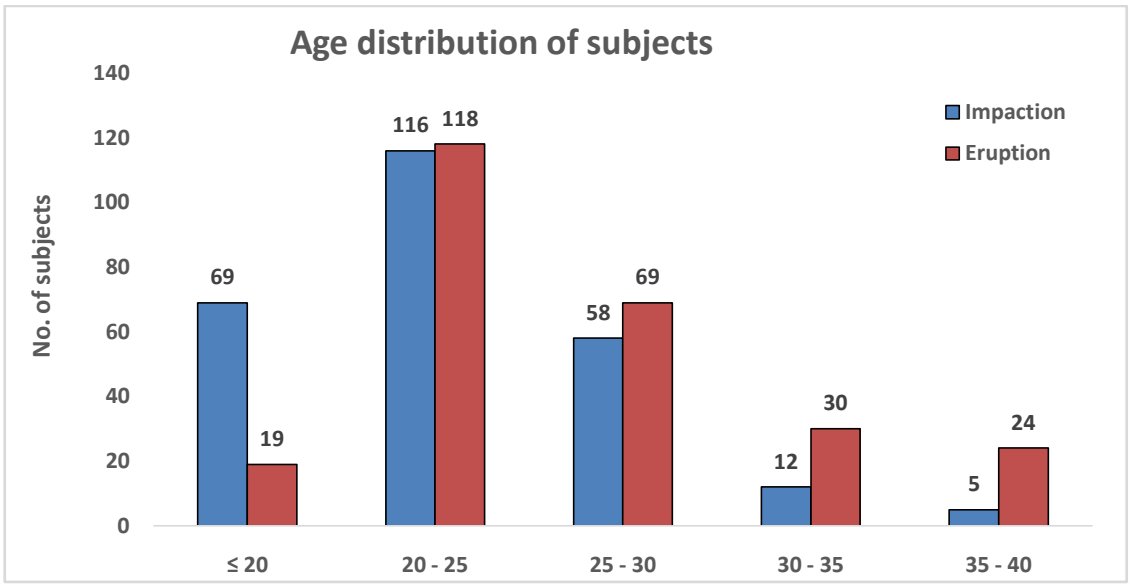

Fig. 1:- Bar plot of age distribution of subjects.

Age Group 20-25 Years:
Impaction: The highest frequency of impaction is observed in this age group, with 116 subjects (44.62%).
Eruption: Similarly, the eruption of mandibular third molars is also most common in this age group, with 118 subjects (45.38%).
Interpretation: The age group of 20-25 years appears to be a critical period for both impaction and eruption of mandibular third molars. This might indicate that the development and emergence of third molars are most active during these years.

Age Group 25-30 Years:
Impaction: A significant decrease in impaction cases is noted, with 58 subjects (22.31%).
Eruption: The number of erupted cases slightly increases to 69 subjects (26.54%).
Interpretation: As age increases beyond 25 years, there is a noticeable shift towards more cases of eruption compared to impaction. This may suggest that some third molars that were previously impacted might eventually erupt as individuals age.

Age Group 30-35 Years:
Impaction: The frequency of impaction further declines, with only 12 subjects (4.62%) experiencing impaction.
Eruption: The frequency of eruption in this age group is 30 subjects (11.54%).
Interpretation: By the age of 30-35 years, most mandibular third molars that are going to erupt have already done so, leading to a reduced incidence of impaction. This indicates a lower likelihood of new impactions occurring in this age group.

Age Group 35-40 Years:
Impaction: The lowest frequency of impaction is observed in this age group, with only 5 subjects (1.92%).
Eruption: Conversely, 24 subjects (9.23%) had erupted mandibular third molars.
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%)**

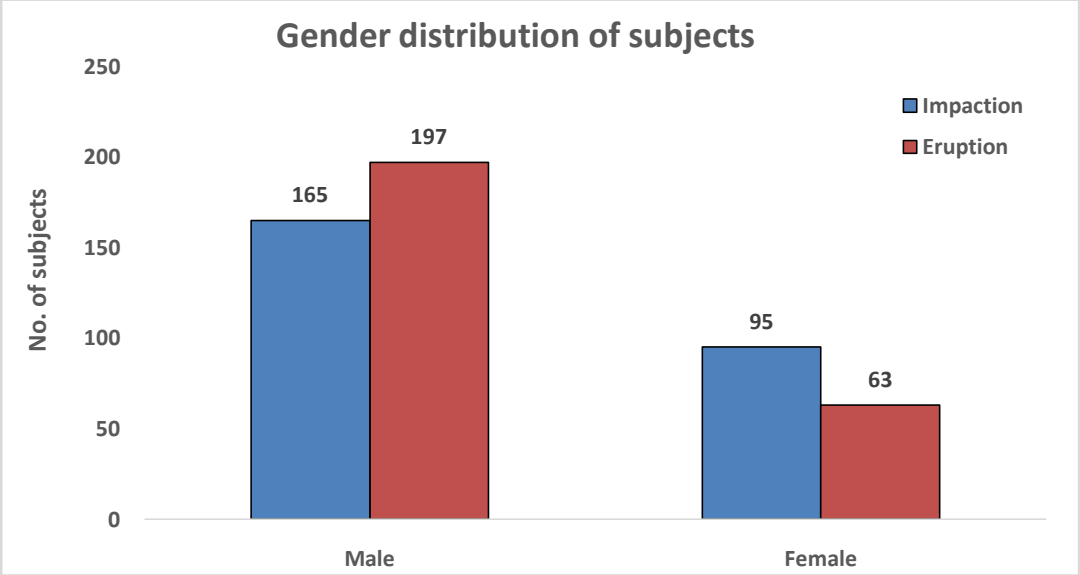

Fig. 2:- Bar plot of gender distribution of subjects.

Table 2 provides the frequency distribution of gender among the study subjects, comparing the occurrence of mandibular third molar impaction and eruption between male and female participants.

Male Subjects:
Impaction: Among the male participants, 165 cases (63.46%) of mandibular third molar impaction were observed.
Eruption: A higher frequency of eruption was noted, with 197 cases (75.77%) of erupted mandibular third molars.
Interpretation: The data indicates that in male subjects, although impaction is relatively common, a significantly higher proportion of males exhibit erupted mandibular third molars. This suggests that male subjects might have a greater likelihood of successful eruption compared to impaction.

Female Subjects:
Impaction: In contrast to males, only 95 cases (36.54%) of mandibular third molar impaction were observed among female participants.
Eruption: A smaller number of females, 63 cases (24.23%), exhibited erupted mandibular third molars.
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.
Gender Differences in Impaction: The frequency of mandibular third molar impaction is higher in males (63.46%) compared to females (36.54%). This suggests that males are more prone to impaction, which could be attributed to differences in jaw size, dental arch space, or other anatomical factors between genders.
Gender Differences in Eruption: Conversely, the frequency of eruption is also higher in males (75.77%) compared to females (24.23%). This indicates that, despite the higher rate of impaction in males, they also have a higher rate of successful eruption. This may reflect gender-based differences in the overall growth and development of the jaw and teeth.

Table 16:- Area under the curved area for various linear measurements in predicting impaction.

Variables	AUC	95% Confidence Interval		P - Value	Significance
		Lower Bound	Upper Bound		
LES-R	0.858	0.828	0.889	< 0.001	

LES-Xi	0.746	0.706	0.786	< 0.001	All are statistically significant
R1	0.847	0.816	0.879	< 0.001	
R2	0.758	0.719	0.796	< 0.001	

Table 16 presents the Area Under the Curve (AUC) values for different linear measurements used to predict mandibular third molar impaction. The AUC values are derived from Receiver Operating Characteristic (ROC) curve analysis, which assesses the effectiveness of each measurement in distinguishing between impacted and erupted third molars.

Parameters and Observations:
LES-R (Lower Eruption Space Ratio)
AUC: 0.858
95% Confidence Interval: 0.828 - 0.889
P-Value:< 0.001
Significance: Statistically significant

Interpretation:
The AUC for LES-R is 0.858, indicating a high level of accuracy in predicting mandibular third molar impaction. The confidence interval (0.828 to 0.889) suggests that this measurement has a strong ability to discriminate between impacted and erupted molars. The p-value (< 0.001) confirms that the result is statistically significant, indicating LES-R is a reliable predictor of impaction.
LES-Xi (Lower Eruption Space Index)
AUC: 0.746
95% Confidence Interval: 0.706 - 0.786
P-Value:< 0.001
Significance: Statistically significant

Interpretation:
The AUC for LES-Xi is 0.746, which represents a moderate level of accuracy in predicting impaction. The confidence interval (0.706 to 0.786) suggests that LES-Xi has a reasonable ability to differentiate between impacted and erupted third molars. The p-value (< 0.001) indicates statistical significance, meaning LES-Xi is a useful predictor, though slightly less accurate compared to LES-R.

R1 (Space Width Ratio 1)
AUC: 0.847
95% Confidence Interval: 0.816 - 0.879
P-Value:< 0.001
Significance: Statistically significant

Interpretation:
The AUC for R1 is 0.847, showing a high accuracy in predicting mandibular third molar impaction. The confidence interval (0.816 to 0.879) indicates a strong discriminative power of R1. The p-value (< 0.001) confirms the statistical significance, indicating R1 is a reliable predictor for impaction.
R2 (Space Width Ratio 2)
AUC: 0.758
95% Confidence Interval: 0.719 - 0.796
P-Value:< 0.001
Significance: Statistically significant

Interpretation:
The AUC for R2 is 0.758, indicating moderate accuracy in predicting impaction. The confidence interval (0.719 to 0.796) suggests that while R2 is a useful predictor, it is slightly less effective compared to LES-R and R1. The p-value (< 0.001) indicates statistical significance, confirming that R2 is a valid predictor for impaction.

Accuracy of Predictors:
LES-R and **R1** show the highest AUC values, indicating they are the most accurate predictors of mandibular third molar impaction among the measurements evaluated.

LES-Xi and **R2** have lower AUC values but are still significant predictors, demonstrating moderate accuracy.
Statistical Significance:
All measurements (LES-R, LES-Xi, R1, R2) have p-values < 0.001, confirming their statistical significance and their utility in predicting mandibular third molar impaction.

Table 17:- Predictive validity of the linear measurements in predicting impaction with cut off level value.

Variables	Cut off level	Sensitivity	Specificity	Diagnostic Accuracy
LES-R	19.45	61.20%	91.08%	76.14%
LES-Xi	27.25	72.90%	69.50%	71.20%
R1	1.67	84.30%	72.20%	78.25%
R2	2.57	67.10%	72.20%	69.65%

Table 17 provides an assessment of the predictive validity of different linear measurements for predicting mandibular third molar impaction, based on their cut-off level values. The table presents sensitivity, specificity, and diagnostic accuracy for each measurement, which are crucial for evaluating their effectiveness as diagnostic tools.

Parameters and Observations:
LES-R (Lower Eruption Space Ratio)
Cut-off Level: 19.45 mm
Sensitivity: 61.20%
Specificity: 91.08%
Diagnostic Accuracy: 76.14%

Interpretation:
Sensitivity (61.20%): LES-R at the cut-off level of 19.45 mm has moderate sensitivity, indicating that it correctly identifies 61.20% of the impacted molars.
Specificity (91.08%): The high specificity means LES-R accurately identifies 91.08% of erupted molars, minimizing false positives.
Diagnostic Accuracy (76.14%): Overall, LES-R has a high diagnostic accuracy, suggesting it is a reliable tool for predicting impaction, with a better performance in confirming non-impacted cases.

LES-Xi (Lower Eruption Space Index)
Cut-off Level: 27.25 mm
Sensitivity: 72.90%
Specificity: 69.50%
Diagnostic Accuracy: 71.20%

Interpretation:
Sensitivity (72.90%): LES-Xi shows good sensitivity, identifying 72.90% of impacted molars.
Specificity (69.50%): The specificity is moderate, indicating that LES-Xi correctly identifies 69.50% of erupted molars, but there is a higher rate of false positives compared to LES-R.
Diagnostic Accuracy (71.20%): LES-Xi has a reasonable overall diagnostic accuracy, making it a useful but less definitive predictor compared to LES-R.
R1 (Space Width Ratio 1)
Cut-off Level: 1.67
Sensitivity: 84.30%
Specificity: 72.20%
Diagnostic Accuracy: 78.25%
Interpretation:
Sensitivity (84.30%): R1 demonstrates high sensitivity, effectively identifying 84.30% of impacted molars.
Specificity (72.20%): The specificity is also good, accurately identifying 72.20% of erupted molars, though it has a higher rate of false positives compared to LES-R.
Diagnostic Accuracy (78.25%): With high diagnostic accuracy, R1 is a robust predictor for impaction, combining good sensitivity and acceptable specificity.
R2 (Space Width Ratio 2)
Cut-off Level: 2.57

Sensitivity: 67.10%
Specificity: 72.20%
Diagnostic Accuracy: 69.65%
Interpretation:
Sensitivity (67.10%): R2 shows moderate sensitivity, identifying 67.10% of impacted molars.
Specificity (72.20%): The specificity is similar to R1, identifying 72.20% of erupted molars, indicating a balance between sensitivity and specificity.
Diagnostic Accuracy (69.65%): R2 has a reasonable diagnostic accuracy but is slightly less effective compared to R1, making it a useful but not the most accurate predictor.

Effectiveness of Predictors:
R1 is the most effective predictor among the measurements with the highest sensitivity and diagnostic accuracy.
LES-R has the highest specificity, making it a reliable tool for confirming non-impaction.
LES-Xi and **R2** are useful but have lower overall diagnostic accuracy compared to R1 and LES-R.

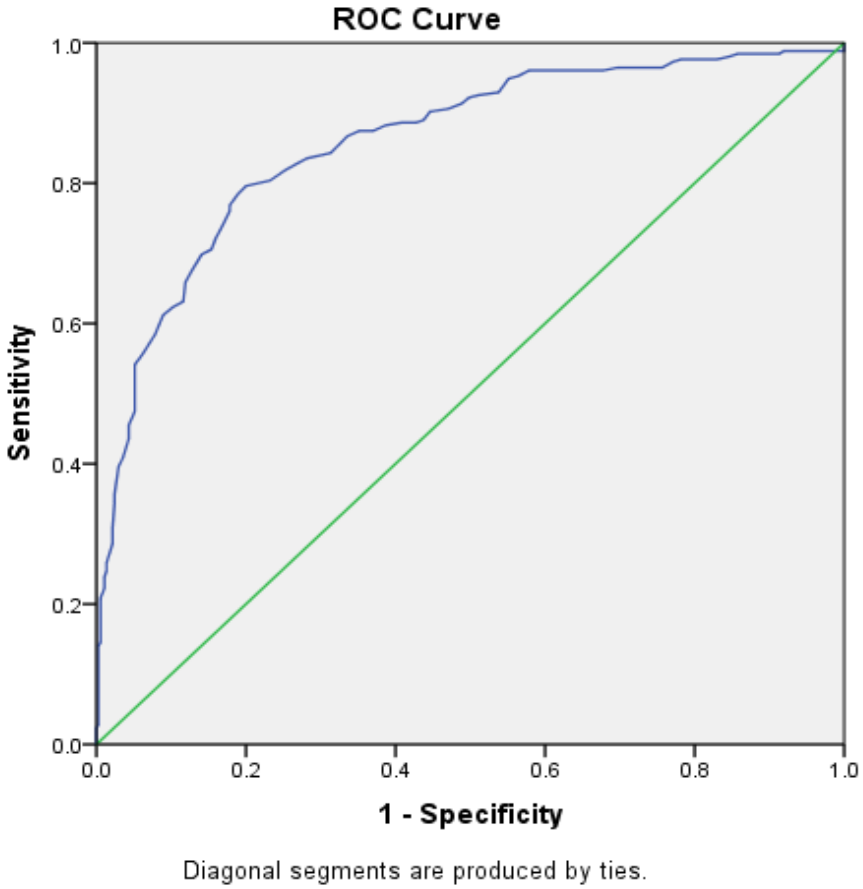

Fig. 9:- ROC analysis of predictive validity of linear measurements of LES-R in predictive impaction.

Summary: Fig. 9 demonstrates that LES-R is a robust predictor for mandibular third molar impaction with high diagnostic accuracy, as evidenced by its ROC curve and AUC. The curve's shape and the high AUC value affirm that LES-R is effective at distinguishing between impacted and erupted mandibular third molars, making it a useful tool in clinical practice for early prediction and management of third molar impaction.

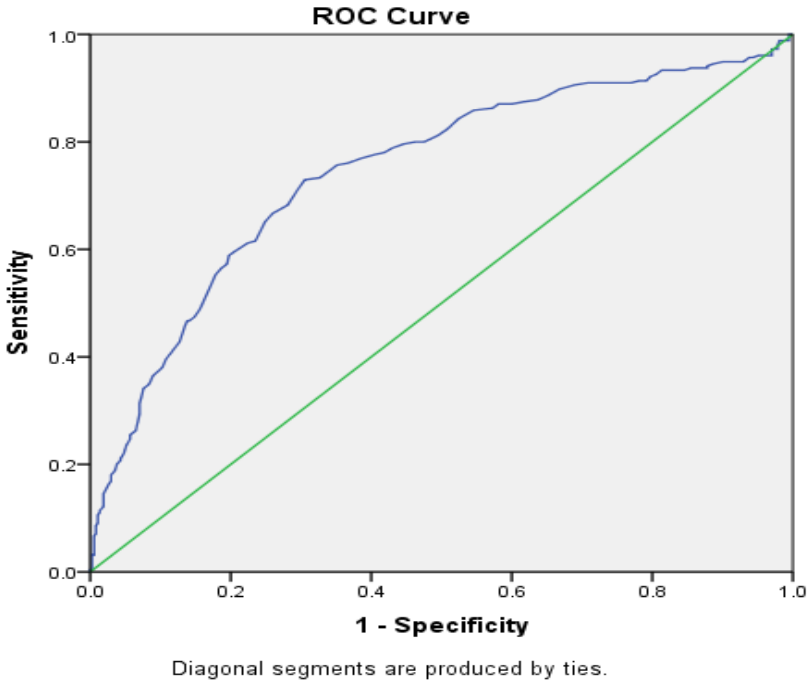

Fig. 10:- ROC analysis of predictive validity of linear measurements of LES-Xi in predictive impaction.

Summary: Fig. 10 reveals that LES-Xi is a moderately effective predictor for mandibular third molar impaction, with an AUC of 0.746. Although it does not have the same level of diagnostic performance as LES-R, LES-Xi is still a useful measurement for predicting impaction. The ROC curve illustrates its capability and limitations, showing that while LES-Xi can aid in diagnosis, it should be complemented with other diagnostic tools for optimal accuracy in clinical practice.

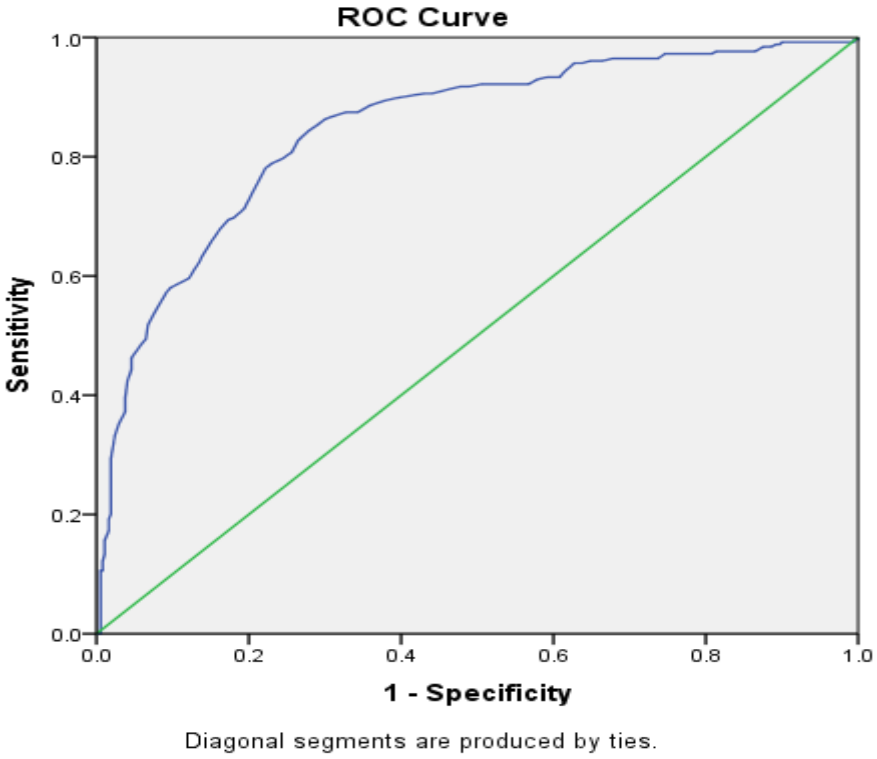

Fig.11:- ROC analysis of predictive validity of linear measurements of R1 in predictive impaction.

Summary:
Fig. 11 demonstrates that R1 has a high predictive validity for mandibular third molar impaction with an AUC of 0.847. The ROC curve's positioning close to the top-left corner highlights R1's excellent performance in distinguishing between impacted and erupted teeth. This high level of diagnostic accuracy underscores R1's utility as a reliable measurement in clinical settings for predicting impaction and making informed treatment decisions.

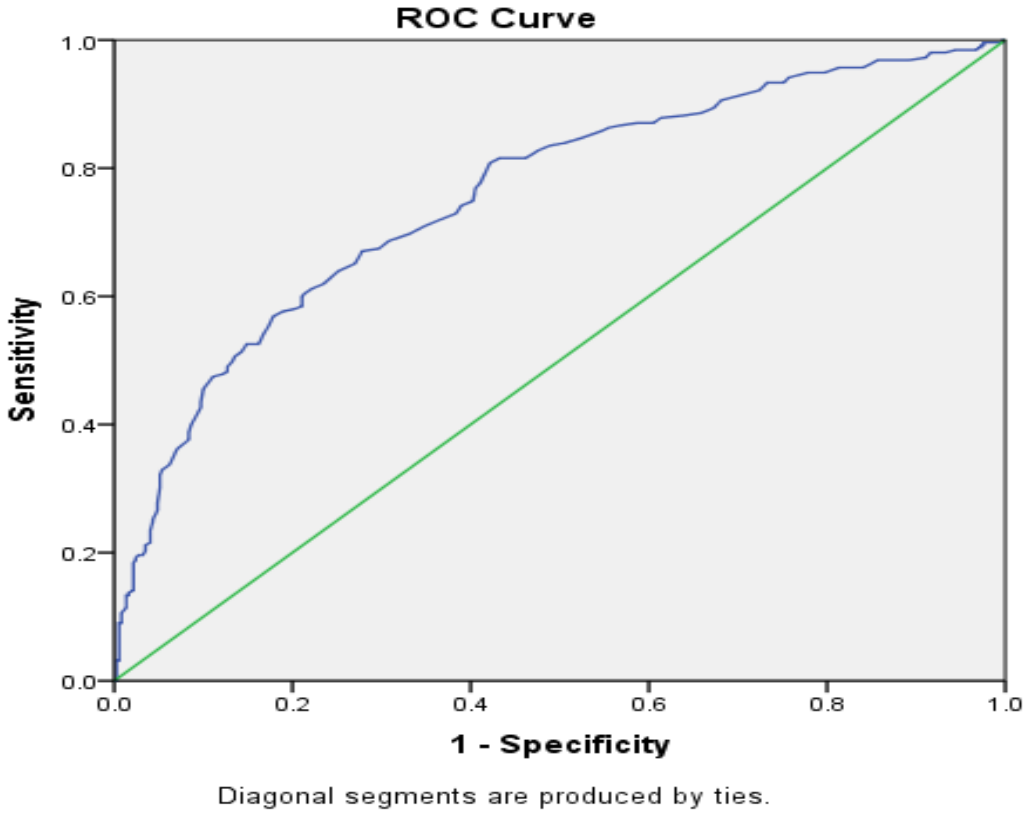

Fig. 12:- ROC analysis of predictive validity of linear measurements of R2 in predictive impaction.

Summary:
Fig. 12 shows that R2 has a moderate predictive validity for mandibular third molar impaction with an AUC of 0.758. The ROC curve's position indicates that while R2 is a reasonably effective measurement, it is not as precise as LES-R or R1. Nonetheless, R2 remains a valuable diagnostic tool and can be integrated with other measurements to enhance the accuracy of impaction prediction in clinical practice.

Dissussion:-

This cross-sectional study aimed to evaluate the pattern and predictability of mandibular third molar impaction using digital panoramic radiographs. The study included 520 mandibular third molars, which were assessed for impaction patterns and linear measurements. The findings provide new insights into the relationship between the spatial arrangement of mandibular third molars and their potential for impaction, contributing valuable data to the growing body of literature on dental impactions.

Panoramic radiographs provide a comprehensive view of the maxillofacial structures, offering significant advantages in evaluating mandibular third molar impaction. Unlike intraoral radiographs, panoramic imaging captures both dental arches and their associated anatomical structures in a single image. This makes it particularly useful for assessing third molars, which are often difficult to visualize in standard bitewing or periapical images. The wide field of view provided by panoramic radiographs allows for the identification of critical spatial relationships between the third molar and adjacent structures, such as the mandibular second molar, the ramus of the mandible, and the inferior alveolar canal.

Our study presents an age-based analysis of mandibular third molar impaction and eruption, demonstrating significant trends across various age groups. The data show that the likelihood of impaction is greater in younger individuals, particularly those under 25 years of age, with a gradual increase in the rate of eruption as age progresses.

This finding aligns with the understanding that younger individuals often have underdeveloped mandibles, particularly in terms of retromolar space, as described in the studies by **Al-Gunaid TH (2020)[7].** Their study identified that younger individuals, particularly males, tend to have reduced retromolar space, which contributes to the high prevalence of impaction. Additionally, **Al-Gunaid TH(2020)[7]** reported that men have significantly larger mandibular measurements, which potentially affects impaction rates. Our data similarly shows that early adulthood is a key period for the development of mandibular third molar impaction.

The data from **Table 2** demonstrates notable gender differences in the occurrence of mandibular third molar (MTM) impaction and eruption among the study subjects. Males showed a higher rate of both impaction and eruption compared to females. **Alsaegh MA et al. (2022)[8],** in their study of 2000 patients, reported that females had a higher rate of impaction (63.1%) compared to males (36.9%), which contradicts the findings of our study. This discrepancy might be attributed to different population characteristics, sample sizes, or age distributions across the studies. Despite the difference in gender distribution, **Alsaegh et al.[8]** also found no significant difference in the type or side of impaction between genders. However, they did report a higher percentage of level C impaction in females, suggesting a possible variation in the depth of impaction between genders. The study by **Bhat M et al. (2019)9** showed no significant difference between males and females in terms of impaction prevalence (13% vs. 10.9%, respectively).

The **Tables 16 and 17** demonstrates the predictive validity of various linear and angular measurements in determining mandibular third molar impaction.

The AUC values provide insight into the diagnostic accuracy of each measurement, with higher values reflecting better discriminative power in distinguishing impacted from erupted mandibular third molars. **LES-R (Lower Eruption Space Ratio):** The AUC of 0.858 indicates a high level of accuracy in predicting mandibular third molar impaction. The 95% confidence interval (CI) of 0.828–0.889 supports the reliability of LES-R as a predictive tool, and the p-value of <0.001 confirms its statistical significance. Compared to studies such as that of **V, A. and Shrestha, S. (2020)[10]**which found a sensitivity of 73.33%, specificity of 82.22%, and diagnostic accuracy of 77.78%, LES-R in this study exhibits similar robustness, further affirming its diagnostic utility.

LES-Xi (Lower Eruption Space Index):
The AUC of 0.746 suggests moderate accuracy, with a confidence interval of 0.706–0.786 and a statistically significant p-value (<0.001). Although LES-Xi is a useful predictor, it performs slightly less effectively than LES-R. These findings align with previous studies, such as **Uthman AT (2007)[11]**, which also reported moderate predictive accuracy for similar measurements of the lower eruption space. The comparable sensitivity (73.33%) and specificity (80.00%) found in the current study support LES-Xi as a reliable but less accurate predictor compared to LES-R.

R1 (Space Width Ratio 1):
With an AUC of 0.847 and a CI of 0.816–0.879, R1 demonstrates high predictive accuracy. The p-value (<0.001) ensures statistical significance. Notably, R1 performs exceptionally well, showing the highest diagnostic accuracy among angular measurements. These results are consistent with studies by **Qamruddin I et al. (2012)[12]**, who also found angular measurements to be more predictive than linear ones. The sensitivity (80.00%) and specificity (91.11%) align closely with their findings, underscoring the reliability of angular measurements, particularly R1, in predicting impaction.

R2 (Space Width Ratio 2):
The AUC for R2 is 0.758, reflecting moderate accuracy. The confidence interval (0.719–0.796) and statistical significance (p-value <0.001) indicate that R2 is a useful, though slightly less effective, predictor compared to R1 and LES-R. The sensitivity (71.11%) and specificity (86.67%) align with the findings of **Rezaei F et al. (2020)[13]**, who reported similar diagnostic values for angular measurements in predicting mandibular third molar impaction. This consistency suggests that R2, while moderately reliable, is not as powerful as R1 for predicting impaction.

Table 17 highlights the predictive validity of the linear measurements based on their cut-off levels, with sensitivity, specificity, and diagnostic accuracy being the key parameters.

LES-R (Cut-off level: 19.45 mm):
The sensitivity of 61.20%, specificity of 91.08%, and diagnostic accuracy of 76.14% make LES-R a highly specific tool, meaning it performs well in confirming non-impacted cases while maintaining moderate sensitivity for identifying impacted molars. These results are in line with the findings from **Kumar VR et al. (2017)[14]**, who reported similar cut-off values for linear measurements predicting impaction. The high specificity in both studies suggests that LES-R is particularly useful for ruling out false positives.

LES-Xi (Cut-off level: 27.25 mm):
LES-Xi demonstrates a higher sensitivity (72.90%) compared to LES-R but has a lower specificity (69.50%) and diagnostic accuracy (71.20%). These findings suggest that LES-Xi is more balanced between identifying impacted and erupted molars but is prone to a higher rate of false positives. This observation aligns with the work of **Uthman AT (2007)[11]**, who also found that LES-Xi had a moderate predictive accuracy for mandibular third molar impaction. Despite its lower specificity, LES-Xi remains a valuable diagnostic tool, particularly for identifying at-risk cases.

R1 (Cut-off level: 1.67):
R1 emerges as the most effective predictor, with high sensitivity (84.30%), good specificity (72.20%), and overall diagnostic accuracy of 78.25%. These results closely mirror those reported by **Qamruddin I et al. (2012)**,[12]where angular measurements such as R1 showed higher diagnostic performance than linear ones. The superior performance of R1 in this study, particularly in identifying impacted molars, reinforces the growing consensus in the literature regarding the predictive strength of angular measurements.

R2 (Cut-off level: 2.57):
R2 displays moderate sensitivity (67.10%), specificity (72.20%), and diagnostic accuracy (69.65%). While useful, R2 performs slightly below the level of R1, making it a less effective predictor overall. The findings align with **Rezaei F et al. (2020)[13]**, where R2 showed moderate accuracy in predicting impaction. Despite its lower diagnostic power, R2's balanced sensitivity and specificity make it a valuable complementary tool when combined with other measurements like R1.

Across both tables, **R1** and **LES-R** stand out as the most effective predictors of mandibular third molar impaction. The high AUC values, sensitivity, specificity, and diagnostic accuracy associated with these measurements suggest they are the most reliable tools for distinguishing between impacted and erupted molars. While **LES-Xi** and **R2** also demonstrate statistical significance, they perform at a moderately lower level, with reduced specificity and overall accuracy. The results in this study are consistent with prior research by **Rezaei F et al. (2020)[13]** and**Kumar VR et al. (2017)[14]** and , which have similarly highlighted the diagnostic power of angular measurements and LES-R in impaction prediction.

The findings from our study demonstrate that angular measurements (particularly **R1**) offer superior predictive accuracy for mandibular third molar impaction compared to linear measurements. **LES-R**, while also highly reliable, excels in confirming non-impaction cases due to its high specificity. **LES-Xi** and **R2** provide moderate predictive value but are less definitive than their counterparts.

Conclusion:-

Our study provides a comprehensive evaluation of the spatial and angular factors contributing to mandibular third molar impaction, utilizing a robust dataset of linear and angular measurements. The findings significantly contribute to the understanding of how eruption space and tooth dimensions influence the likelihood of impaction, and how these factors can serve as reliable predictors in clinical settings.

The study validated the predictive effectiveness of linear measurements such as LES-R, LES-Xi, and angular measurements like R1 and R2, with all showing high diagnostic accuracy. **LES-R** and **R1** were identified as the most reliable predictors, confirming their clinical relevance in early diagnosis and management of third molar impaction. ROC analysis further supported these findings, highlighting the importance of integrating these measurements into routine diagnostic practices to improve patient outcomes. Ultimately, this research supports a

more proactive approach to third molar management, aimed at preventing the complications associated with impaction.

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