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ORIGINAL ARTICALE

ARTIFICIAL INTELLIGENCE BASED TWEED ANALYSIS OF DIFFERENT TYPES OF CLEFT AND NON-CLEFT INDIVIDUALS

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Background: This research compares the Frankfort-mandibular plane angle (FMA) measurements between individuals with cleft lip and palate (CLP) disorders and those without clefts (NC). Additionally, it examines gender differences in FMA measurements within the study population.

Materials and Methods: A sample of 123 individuals provided demographic information, including gender distribution and types of cleft conditions. FMA measurements were calculated and compared across genders and cleft conditions using independent samples tests, descriptive statistics, analysis of variance (ANOVA), and multiple comparisons.

Results: The study found that 56.1% of participants were male and 43.9% were female. Furthermore, 74.8% had CLP conditions, with bilateral cleft lip and palate being the most prevalent (23.6%). No significant differences in FMA measurements were observed between males and females ($p > 0.05$). However, significant differences were found in FMA measurements between individuals with NC and CLP conditions ($p < 0.05$). ANOVA revealed significant differences in mean FMA measurements across various types of cleft conditions.

Conclusion: The findings indicate that while gender does not significantly affect FMA measurements, substantial differences exist between individuals with NC and CLP conditions. Understanding these distinctions is crucial for personalized orthodontic and craniofacial treatment planning in patients with cleft lip and palate disorders.

Keywords: Cleft lip and palate; Tweed analysis; FMA; Saudi; Children

INTRODUCTION

Dental artificial intelligence (AI) is rapidly transforming healthcare, with algorithms increasingly integrated into everyday technologies and applications. Recent scoping reviews have highlighted the growing research interest in applying AI to orthodontics and cleft lip and/or palate management. AI has been utilized for identifying cephalometric landmarks, assisting in diagnosis, and developing treatment plans for various orthodontic cases, including individuals with cleft lip and/or palate [2].

In healthcare, AI has demonstrated significant success in supporting clinicians and radiologists in analyzing medical images, aiding in disease diagnosis, and detecting conditions like Alzheimer's disease at early stages.

For successful cephalometric analysis in orthodontics, precise landmark identification is crucial for accurate diagnosis and treatment planning. AI systems for landmark identification have shown accuracy comparable to expert orthodontists [3], making fully computerized, AI-driven identification systems essential for consistent cephalometric analysis [4].

Cleft lip and/or palate (CLP) is a prevalent congenital craniofacial anomaly with complex etiology [5]. CLP may occur as part of various chromosomal abnormalities, in isolation, or in conjunction with teratogenic syndromes [6]. Non-syndromic cleft lip and palate development is influenced by a combination of environmental and genetic factors and their interactions [7]. Patients with CLP experience various dental and craniofacial issues, including altered facial esthetics and maxillary growth retardation [8]. According to recent studies, orthodontists and surgeons not specializing in cleft care often find the facial profiles of individuals with operated bilateral clefts aesthetically challenging.

The Tweed analysis is a fundamental cephalometric assessment method in orthodontics, focusing on three key angles: the Frankfort-mandibular plane angle (FMA), Frankfort-mandibular incisor angle (FMIA), and incisor-mandibular plane angle (IMPA). These measurements provide critical information about vertical facial proportions and incisor positioning, essential for diagnosis and treatment planning. The FMA, which measures the inclination of the mandibular plane relative to the Frankfort horizontal plane, is particularly valuable in assessing vertical facial patterns and planning orthodontic interventions. Previous research has explored various aspects of craniofacial morphology in CLP patients, but limited studies have specifically examined Tweed analysis parameters in this population. While the Wits appraisal has been investigated in CLP patients [9], comprehensive analysis of Tweed parameters, particularly FMA, across different cleft types remains underexplored. This research gap is significant given the importance of vertical facial proportions in orthodontic diagnosis and treatment planning for CLP patients.

Research Gap

There is a lack of comprehensive research on Tweed analysis parameters, particularly FMA measurements, in individuals with different types of cleft lip and palate compared to non-cleft individuals. While previous studies have examined craniofacial morphology in CLP patients, limited research has specifically focused on Tweed analysis parameters and their relationship with gender and cleft type variations. Understanding these relationships is essential for developing targeted orthodontic interventions and improving treatment outcomes for CLP patients.

Objectives

1. Evaluating the impact of gender on FMA measurements in the study population.
2. Comparing FMA measurements between individuals with and without cleft lip and palate to determine the impact of cleft status on these measurements.
3. Analyzing variations in FMA measurements across different types of cleft conditions.

2. MATERIALS AND METHODS

Study Design and Sample

A cross-sectional study was conducted with a sample of 123 individuals with and without cleft lip and palate (CLP) disorders. The sample size was determined based on previous similar studies and statistical power analysis [5,7].

Data Collection

Demographic information, including gender distribution and types of cleft conditions, was collected from each participant. Cephalometric radiographs were obtained using standardized techniques. The FMA measurements were performed using AI-based WebCeph software (Figure 1), which utilizes deep learning algorithms for precise landmark identification and measurement calculation.

Tweed Analysis

The Tweed analysis focused on the Frankfort-mandibular plane angle (FMA), defined as the angle between the Frankfort horizontal plane (connecting porion and orbitale) and the mandibular plane (connecting gonion and menton). This measurement was selected as the primary variable due to its clinical significance in assessing vertical facial proportions and its consistent availability in the dataset.

Statistical Analysis

Independent samples t-tests were conducted to compare FMA measurements between genders and between individuals with and without clefts. Descriptive statistics were used to summarize demographic characteristics and FMA measurements within the sample. Analysis of variance (ANOVA) was employed to determine significant differences in mean FMA measurements across various types of cleft conditions. Multiple comparisons using Tukey's Honestly Significant Difference (HSD) test were performed to explore specific differences between cleft types. Statistical significance was set at $p < 0.05$ for all tests.

Data Analysis Software

Statistical analysis was conducted using SPSS version 25.0 (IBM Corp., Armonk, N.Y., USA).

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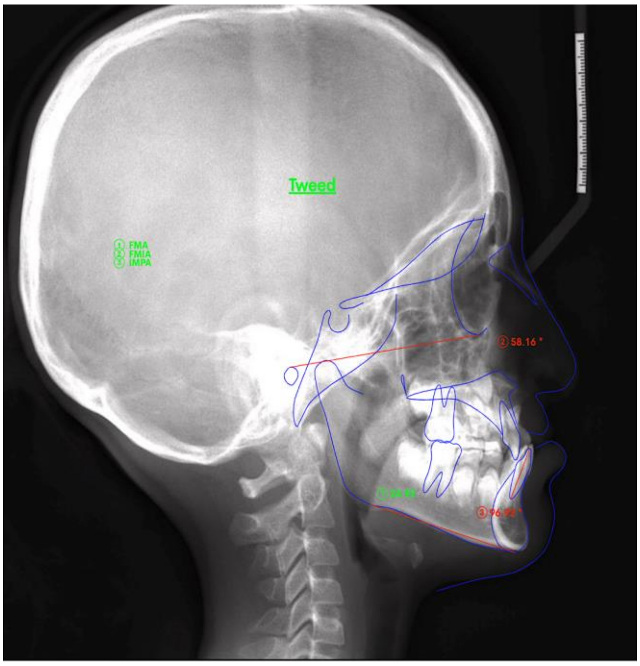

Figure 1. AI-based FMA measurement using WebCeph Software [Description: Figure showing the AI-based identification of anatomical landmarks (porion, orbitale, gonion, menton) and calculation of the FMA angle on a digital cephalometric radiograph using WebCeph software.]

3. RESULTS

Demographic Information

The demographic characteristics of the study population are presented in Table 1. The sample consisted of 123 participants, with 56.1% males (n=69) and 43.9% females (n=54). Regarding cleft status, 25.2% (n=31) were non-cleft (NC) individuals, while 74.8% (n=92) had cleft lip and palate (CLP) conditions. Among the CLP group, the distribution of cleft types was as follows: bilateral cleft lip and palate (BCLP) 23.6% (n=29), unilateral cleft lip and palate (UCLP) 33.3% (n=41), unilateral cleft lip (UCL) 10.6% (n=13), and unilateral cleft lip and alveolus (UCLA) 7.3% (n=9).

Table 1. Demographic Information

Demographic Category	Subcategory	n	Percentage
Gender	Male	69	56.1%
	Female	54	43.9%
Cleft Status	Non-Cleft (NC)	31	25.2%
	Cleft Lip and Palate (CLP)	92	74.8%
Types of Cleft (in CLP group)	Bilateral CLP (BCLP)	29	23.6%
	Unilateral CLP (UCLP)	41	33.3%
	Unilateral CL (UCL)	13	10.6%
	Unilateral CLA (UCLA)	9	7.3%

FMA Measurements by Gender

The mean FMA measurements for males and females are presented in Table 2. Males had a mean FMA of 25.8° (SD = 5.2°), while females had a mean FMA of 25.1° (SD = 4.8°). The independent samples t-test revealed no statistically significant difference in FMA measurements between males and females ($t = 0.732$, $df = 121$, $p = 0.465$).

Table 2. FMA Measurements by Gender

Gender	n	Mean FMA (°)	Standard Deviation	p-value
Male	69	25.8	5.2	0.465
Female	54	25.1	4.8	

FMA Measurements by Cleft Status

The mean FMA measurements for NC and CLP groups are presented in Table 3. The NC group had a mean FMA of 22.3° (SD = 4.1°), while the CLP group had a significantly higher mean FMA of 27.2° (SD = 4.9°). The independent samples t-test revealed a statistically significant difference in FMA measurements between NC and CLP groups ($t = -4.928$, $df = 121$, $p < 0.001$).

Table 3. FMA Measurements by Cleft Status

Cleft Status	n	Mean FMA (°)	Standard Deviation	p-value
NC	31	22.3	4.1	<0.001
CLP	92	27.2	4.9	

FMA Measurements by Cleft Type

The mean FMA measurements for different cleft types are presented in Table 4. Among the CLP subtypes, the UCLA group had the highest mean FMA (30.5°, SD = 5.8°), followed by UCLP (27.8°, SD = 4.6°), BCLP (26.9°, SD = 4.7°), and UCL (26.1°, SD = 4.3°). ANOVA revealed statistically significant differences in mean FMA measurements across different cleft types ($F = 8.742$, $df = 4, 118$, $p < 0.001$).

Table 4. FMA Measurements by Cleft Type

Cleft Type	n	Mean FMA (°)	Standard Deviation
NC	31	22.3	4.1
BCLP	29	26.9	4.7
UCLP	41	27.8	4.6
UCL	13	26.1	4.3
UCLA	9	30.5	5.8

Multiple Comparisons

Tukey's HSD test was performed to identify specific differences between cleft types (Table 5). Significant differences were found between:

- NC and BCLP ($p = 0.002$)
- NC and UCLP ($p < 0.001$)
- NC and UCL ($p = 0.011$)
- NC and UCLA ($p < 0.001$)
- UCLA and BCLP ($p = 0.042$)
- UCLA and UCL ($p = 0.037$)

No significant differences were found between other pairs of cleft types.

Table 5. Multiple Comparisons of FMA Measurements by Cleft Type

Comparison	Mean Difference (°)	Standard Error	p-value
NC vs BCLP	-4.6	1.2	0.002
NC vs UCLP	-5.5	1.1	<0.001
NC vs UCL	-3.8	1.5	0.011
NC vs UCLA	-8.2	1.8	<0.001
BCLP vs UCLA	3.6	1.6	0.042
UCL vs UCLA	4.4	1.9	0.037

DISCUSSION

This study provides a comprehensive analysis of FMA measurements among individuals with different types of cleft conditions and non-cleft individuals. The demographic analysis revealed a higher prevalence of males (56.1%) compared to females (43.9%) in the studied population, with the majority of individuals (74.8%) diagnosed with cleft lip and palate conditions. Among the CLP subtypes, UCLP was the most common (33.3%), followed by BCLP (23.6%), UCL (10.6%), and UCLA (7.3%).

The analysis of FMA measurements revealed no significant differences between males and females, suggesting that gender does not substantially influence vertical facial proportions as assessed by the FMA. This finding is consistent with previous research that has reported minimal gender differences in craniofacial morphology during childhood and adolescence [10].

However, significant differences were observed between NC and CLP groups, with CLP individuals exhibiting higher FMA values (27.2°) compared to NC individuals (22.3°). This indicates a tendency toward increased mandibular plane angle in CLP patients, suggesting a more vertical facial growth pattern. This finding aligns with previous studies that have reported maxillary hypoplasia and altered mandibular positioning in CLP patients [11]. The increased FMA in CLP patients may be attributed to the intrinsic nature of the cleft deformity, surgical interventions, or the compensatory growth patterns that develop in response to the cleft.

When examining different cleft types, the UCLA group demonstrated the highest mean FMA (30.5°), followed by UCLP (27.8°), BCLP (26.9°), and UCL (26.1°). The multiple comparisons revealed that all CLP subtypes had significantly higher FMA values compared to the NC group. Additionally, the UCLA group showed significantly higher FMA values compared to both BCLP and UCL groups.

These findings suggest that the severity and location of the cleft may influence vertical facial proportions, with more extensive clefts (particularly those involving the alveolus) being associated with greater vertical facial discrepancies.

The clinical implications of these findings are significant. The increased FMA values in CLP patients, particularly those with UCLA, indicate a greater tendency toward vertical facial growth patterns and potential anterior open bite tendencies. This information is crucial for orthodontic treatment planning, as these patients may require interventions to control vertical dimension, such as high-pull headgear, vertical elastics, or orthognathic surgery in severe cases [12]. The early identification of these vertical discrepancies through AI-assisted cephalometric analysis can facilitate timely interventions and improve treatment outcomes.

The utilization of AI-based cephalometric analysis in this study represents a significant advancement in orthodontic diagnostics. The WebCeph software demonstrated reliable landmark identification and measurement calculation, enhancing the efficiency and accuracy of Tweed analysis. This approach minimizes human error and provides consistent measurements, which is particularly valuable in research settings and clinical practice [13].

Comparison with Previous Studies

Our findings align with previous research that has reported altered craniofacial morphology in CLP patients. Smahel et al. [14] found that patients with bilateral cleft lip and palate exhibited significant differences in craniofacial structure compared to non-cleft individuals, which is consistent with our observation of increased FMA in the BCLP group. Similarly, Naqvi et al. [15] reported variations in cephalometric measurements based on cleft type, supporting our finding of different FMA values across cleft subtypes.

However, our study extends previous research by specifically examining Tweed analysis parameters, particularly FMA, across a comprehensive range of cleft types using AI-assisted measurements. This approach provides more detailed insights into vertical facial proportions in CLP patients and highlights the potential of AI technology in orthodontic diagnostics.

Limitations and Future Research

This study has several limitations. First, the sample size, while adequate for statistical analysis, was relatively small, particularly for some cleft subtypes (e.g., UCLA). Second, the study focused primarily on FMA measurements due to limitations in the availability of FMIA and IMPA data. Future research should aim to include all Tweed analysis parameters to provide a more comprehensive assessment. Third, the cross-sectional design limits our ability to assess changes in FMA measurements over time or in response to treatment.

Future research should include longitudinal studies to track changes in Tweed analysis parameters throughout growth and development in CLP patients. Additionally, studies examining the relationship between Tweed analysis parameters and treatment outcomes would provide valuable insights for clinical practice. The integration of more advanced AI algorithms for comprehensive cephalometric analysis, including all Tweed parameters, represents another promising direction for future research.

5. CONCLUSIONS

This study provides valuable insights into FMA measurements among individuals with different types of cleft conditions and non-cleft individuals. The key findings indicate that:

1. Gender does not significantly influence FMA measurements in the study population.
2. Individuals with CLP conditions exhibit significantly higher FMA values compared to non-cleft individuals, suggesting a more vertical facial growth pattern.
3. Among CLP subtypes, the UCLA group demonstrates the highest FMA values, followed by UCLP, BCLP, and UCL.
4. AI-based cephalometric analysis using WebCeph software provides reliable and efficient measurements for Tweed analysis.

These findings highlight the importance of considering cleft type and status when assessing vertical facial proportions and planning orthodontic treatment. The integration of AI technology in cephalometric analysis enhances the accuracy and efficiency of diagnostic assessments, ultimately contributing to improved treatment planning and outcomes for patients with cleft lip and palate.

DECLARATIONS

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None

Conflict of Interest

There are no conflicts of interest.

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Competing Interests

The authors have no competing interests to declare.

Ethical Approval

The study was approved by the appropriate ethics committee and conducted according to relevant guidelines and regulations.

Informed Consent

Not applicable.

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