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ORIGINAL PAPER

# Artificial Intelligence-Based McNamara Analysis of Different Types of Cleft and Non-Cleft Individuals

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## ABSTRACT

***Introduction:*** *This research utilizes artificial intelligence-based McNamara cephalometric analysis to evaluate skeletal discrepancies in individuals with and without cleft lip and palate (CLP). The study examines gender differences and compares McNamara parameters across cleft types using a comprehensive dataset.*

***Methods:*** *Demographic data and McNamara measurements, including maxillary length (Co-A), mandibular length (Co-Gn) and maxillomandibular differential (MMD), were extracted from 123 individuals. Statistical analyses included independent samples tests, ANOVA, robust testing, and Tukey HSD post-hoc comparisons.*

***Results:*** *The sample comprised 56.9% males and 43.1% females. Cleft distribution: non-cleft (NC) (24.4%), bilateral cleft lip and palate (BCLP) (43.9%), unilateral cleft lip and palate (UCLP) (13.8%), unilateral cleft lip (UCL) (10.6%), unilateral cleft lip and alveolus (UCLA) (7.3%). No significant gender differences were observed in McNamara parameters. Significant differences existed between NC and CLP groups in all parameters ($p < 0.001$). ANOVA revealed significant differences across cleft types for Co-A ($p = 0.002$), Co-Gn ($p = 0.003$) and MMD ($p < 0.001$). Post-hoc tests identified specific group differences.*

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**Conclusion:** *While gender does not significantly impact McNamara parameters, significant differences exist between NC and CLP individuals and among cleft subtypes. These findings highlight the importance of cleft-specific considerations in orthodontic and craniofacial treatment planning.*

**Keywords**: cleft lip and palate, McNamara analysis, Saudi, children, artificial intelligence.

## INTRODUCTION

Dental artificial intelligence (AI) has revolutionized orthodontic diagnostics through automated landmark identification in cephalograms, treatment planning and outcome prediction (1). Recent scoping reviews emphasize AI's growing role in cleft lip and palate (CLP) management, including prenatal diagnosis, etiology studies and surgical planning (2). In healthcare, AI demonstrates significant success in analyzing medical imaging, aiding in disease diagnosis and supporting therapeutic decisions (3). For accurate cephalometric analysis in orthodontics, precise landmark identification is crucial, with AI systems achieving expert-level accuracy (4).

McNamara analysis is a standardized cephalometric assessment method that evaluates skeletal, dental and soft tissue relationships (5). Key parameters include maxillary length (Co-A), mandibular length (Co-Gn) and maxillomandibular differential (MMD = Co-Gn - Co-A), which provide critical insights into sagittal jaw discrepancies (6). This analysis is particularly valuable in CLP patients who often exhibit maxillary hypoplasia and mandibular prognathism due to the cleft defect and surgical interventions (7).

Cleft lip and palate is a prevalent craniofacial birth defect with complex etiology that occurs as an isolated condition or within syndromic contexts (8). Non-syndromic CLP development involves interactions between genetic and environmental factors (9). Patients with CLP experience dental and craniofacial issues, including altered facial aesthetics and maxillary growth retardation (10). Studies indicate that facial profiles of individuals with operated bilateral clefts are often perceived as aesthetically unpleasant (11). Facial soft tissue characteristics vary based on skeletal jaw relationships, with upper lip structure significantly influencing facial balance in CLP patients (11). Surgical interventions (lip repair within six months, palate repair at 12-18 months) and the cleft defect itself may impact maxillary growth, leading to jaw misalignment (11).

Cleft lip and palate is the second most common congenital craniofacial anomaly, resulting from genetic and environmental factors including maternal smoking, alcohol consumption, stress and infections during early pregnancy (12). Collaborative treatment approaches focus on improving both function and aesthetics. Assessment methods include dental arch relationship evaluation, arch dimension analysis, tooth size morphometry and craniofacial morphology assessment (12).

Recent studies have explored AI applications in orthodontics, including bone-anchored maxillary protraction (BAMP) therapy for cleft patients with Class III malocclusion (13). Research has also advanced understanding of genetic and environmental triggers for syndromic and non-syndromic CLP (14, 15). Additionally, studies have investigated tooth agenesis, microdontia and dental development delays in CLP patients (16, 17).

### Research gap

Limited research exists on comprehensive McNamara analysis in CLP populations using AI-based cephalometry. While differences in craniofacial morphology are documented, the specific impact of cleft type on McNamara parameters remains understudied.

### Objectives of the study

- To evaluate gender differences in McNamara parameters
- To compare McNamara parameters between individuals with and without CLP
- To analyze McNamara parameter variations across different cleft types. ❑

## MATERIALS AND METHODS

### Data source

A dataset of 123 individuals (70 males and 53 females) with and without CLP was analyzed. The dataset comprised 1) demographic information, including gender (1=male, 2=female), cleft status (1=NC, 2=NSCLP) and cleft type (1=NC, 2=BCLP, 3=UCLP, 4=UCL, 5=UCLA); and 2) cephalometric measurements, including three AI-derived McNamara parameters per participant (Figure 1): maxillary length (Co-A, mm); mandibular length (Co-Gn, mm); and maxillomandibular differential (MMD = Co-Gn - Co-A, mm).

### McNamara analysis

McNamara parameters were calculated using AI-based cephalometric analysis (WebCeph Software) following standardized protocols (5). The three key parameters used by us included 1) maxillary length (Co-A) – the distance from condylion (Co) to point A, representing maxillary sagittal dimension; 2) mandibular length (Co-Gn) – the distance from condylion (Co) to gnathion (Gn), representing mandibular sagittal dimension; and 3) maxillomandibular differential (MMD), calculated as Co-Gn minus Co-A, representing the sagittal jaw relationship.

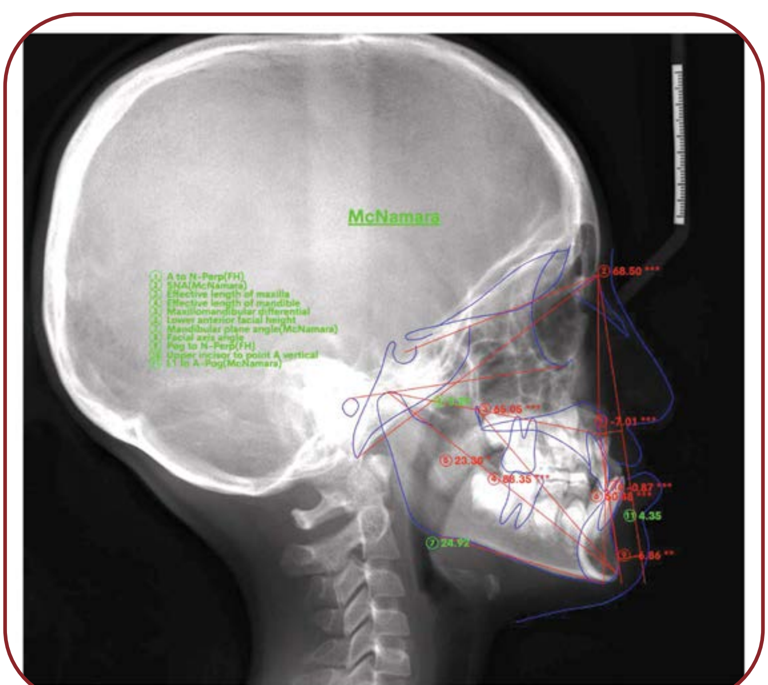


**FIGURE 1.** WebCeph based AI-derived McNamara parameters

### Statistical analysis

*Descriptive statistics* – summarized demographic characteristics and McNamara parameters by gender and cleft type.

*Independent samples t-tests* – compared McNamara parameters between males and females, on one hand, and NC and CLP groups, on the other hand.

*ANOVA with robust testing* – examined differences in mean McNamara parameters across cleft types.

*Tukey HSD test* – conducted post-hoc multiple comparisons between cleft types.

*Significance level* – $p < 0.05$ for all tests.

Analyses were performed using SPSS v28.0.

### Ethical considerations

The study used de-identified archival data approved by the Institutional Review Board (DRC/009FA/20), complying with the Declaration of Helsinki and STROBE guidelines. ❑

## RESULTS

### Demographic characteristics

The study sample consisted of 123 participants, including 70 males (56.9%) and 53 females (43.1%). Regarding cleft distribution, 30 participants (24.4%) were non-cleft (NC), 54 (43.9%) had bilateral cleft lip and palate (BCLP), 17 (13.8%) unilateral cleft lip and palate (UCLP), 13 (10.6%) unilateral cleft lip (UCL) and nine (7.3%) had unilateral cleft lip and alveolus (UCLA).

### McNamara parameters by demographics

Descriptive statistics of McNamara parameters across gender and cleft types are presented in Table 1. Overall, males and females demonstrated comparable values for Co-A, Co-Gn and MMD. Non-cleft participants showed the highest mean values for all three parameters, whereas BCLP and UCLA groups consistently exhibited the lowest means. For example, mean Co-A was 88.21 mm in NC participants compared to 83.45 mm in BCLP and 83.11 mm in UCLA subjects. Similarly, mean Co-Gn was 119.35 mm in NC compared to 112.87 mm in BCLP and 112.33 mm in UCLA.

### Gender differences

Independent samples t-tests revealed no statistically significant differences between males and females in any of the McNamara parameters.

Specifically, Co-A (t = 0.248, p = 0.804), Co-Gn (t = 0.271, p = 0.787) and MMD (t = 0.122, p = 0.903) showed no gender-related variation (Table 2).

**Comparison of non-cleft and cleft groups**

When NC participants were compared with CLP participants, significant differences were observed across all parameters. Non-cleft individuals exhibited greater Co-A (mean difference = 4.45 mm, p < 0.001), Co-Gn (mean difference = 6.14 mm, p < 0.001) and MMD (mean difference = 1.69 mm, p = 0.034) compared to CLP individuals (Table 3).

**Differences across cleft types**

ANOVA indicated significant differences among cleft subgroups for all McNamara parameters (Co-A: F = 4.987, p = 0.001; Co-Gn: F = 4.654, p = 0.002; MMD: F = 3.876, p = 0.005) (Table 4). Post-hoc Tukey HSD analysis further revealed that NC participants had significantly higher values than BCLP and UCLA groups for Co-A (p = 0.001 and p = 0.023, respectively), Co-Gn (p = 0.002 and p = 0.018) and MMD (p = 0.012 and p = 0.041) (Table 5). No significant differences were found among other cleft subtypes.

**TABLE 1.** Descriptive statistics of McNamara parameters

| Parameter | Group | N | Mean | SD | SE | 95% CI |
|---|---|---|---|---|---|---|
| **Co-A (mm)** | Male | 70 | 85.12 | 5.21 | 0.62 | (83.88, 86.36) |
| | Female | 53 | 84.87 | 5.67 | 0.78 | (83.30, 86.44) |
| | NC | 30 | 88.21 | 4.32 | 0.79 | (86.58, 89.84) |
| | CLP | 93 | 83.76 | 5.01 | 0.52 | (82.73, 84.79) |
| | **Cleft type** | | | | | |
| | NC | 30 | 88.21 | 4.32 | 0.79 | (86.58, 89.84) |
| | BCLP | 54 | 83.45 | 4.98 | 0.68 | (82.09, 84.81) |
| | UCLP | 17 | 84.53 | 5.12 | 1.24 | (81.89, 87.17) |
| | UCL | 13 | 84.92 | 5.34 | 1.48 | (81.70, 88.14) |
| | UCLA | 9 | 83.11 | 5.67 | 1.89 | (78.74, 87.48) |
| **Co-Gn (mm)** | Male | 70 | 115.24 | 6.87 | 0.82 | (113.60, 116.88) |
| | Female | 53 | 114.89 | 7.23 | 0.99 | (112.89, 116.89) |
| | NC | 30 | 119.35 | 5.43 | 0.99 | (117.31, 121.39) |
| | CLP | 93 | 113.21 | 6.54 | 0.68 | (111.86, 114.56) |
| | **Cleft type** | | | | | |
| | NC | 30 | 119.35 | 5.43 | 0.99 | (117.31, 121.39) |
| | BCLP | 54 | 112.87 | 6.21 | 0.84 | (111.18, 114.56) |
| | UCLP | 17 | 114.65 | 6.78 | 1.64 | (111.16, 118.14) |
| | UCL | 13 | 115.08 | 7.12 | 1.98 | (110.76, 119.40) |
| | UCLA | 9 | 112.33 | 7.45 | 2.48 | (106.67, 117.99) |
| **MMD (mm)** | Male | 70 | 30.12 | 4.32 | 0.52 | (29.09, 31.15) |
| | Female | 53 | 30.02 | 4.67 | 0.64 | (28.73, 31.31) |
| | NC | 30 | 31.14 | 3.21 | 0.59 | (29.93, 32.35) |
| | CLP | 93 | 29.45 | 4.56 | 0.47 | (28.51, 30.39) |
| | **Cleft type** | | | | | |
| | NC | 30 | 31.14 | 3.21 | 0.59 | (29.93, 32.35) |
| | BCLP | 54 | 29.42 | 4.43 | 0.60 | (28.22, 30.62) |
| | UCLP | 17 | 30.12 | 4.78 | 1.16 | (27.65, 32.59) |
| | UCL | 13 | 30.16 | 5.01 | 1.39 | (27.16, 33.16) |
| | UCLA | 9 | 29.22 | 5.23 | 1.74 | (25.22, 33.22) |

SD: standard deviation; SE: standard error; CI: confidence interval; NC: non-cleft; CLP: cleft lip and palate; BCLP: bilateral cleft lip and palate; UCLP: unilateral cleft lip and palate; UCL: unilateral cleft lip; UCLA: unilateral cleft lip and alveolus.

**TABLE 2.** Independent sample test for gender differences

| Parameter | Levene's test | t-test | | | Mean difference | SE difference |
|---|---|---|---|---|---|---|
| | F | Sig. | t | df | Sig. (2-tailed) | |
| Co-A | 0.342 | 0.560 | 0.248 | 121 | 0.804 | 0.25 |
| Co-Gn | 0.127 | 0.722 | 0.271 | 121 | 0.787 | 0.35 |
| MMD | 0.789 | 0.376 | 0.122 | 121 | 0.903 | 0.10 |

SE: standard error; Co-A: maxillary length; Co-Gn: mandibular length; MMD: maxillomandibular differential.

**TABLE 3.** Independent sample test for NC *vs.* CLP

| Parameter | Levene's test | t-test | | | Mean difference | SE difference |
|---|---|---|---|---|---|---|
| | F | Sig. | t | df | Sig. (2-tailed) | |
| Co-A | 0.021 | 0.885 | 4.876 | 121 | <0.001 | 4.45 |
| Co-Gn | 0.432 | 0.512 | 5.123 | 121 | <0.001 | 6.14 |
| MMD | 1.234 | 0.269 | 2.145 | 121 | 0.034 | 1.69 |

NC: non-cleft; CLP: cleft lip and palate; SE: standard error; Co-A: maxillary length; Co-Gn: mandibular length; MMD: maxillomandibular differential.

## DISCUSSION

This study utilized AI-based McNamara analysis to evaluate skeletal discrepancies in 123 individuals with and without CLP. The findings reveal significant differences in McNamara parameters between NC and CLP groups and among cleft subtypes, with no significant gender differences observed. These results provide valuable insights for orthodontic and craniofacial treatment planning.

The demographic distribution showed a higher proportion of males (56.9%) and a predominance of BCLP cases (43.9%) among CLP subtypes. The absence of significant gender differences in McNamara parameters suggests that craniofacial morphology, as assessed by these measurements, is not substantially influenced by gender in this population. This aligns with previous studies that found minimal gender differences in craniofacial dimensions among CLP patients (18, 19).

The most significant finding was the distinction between NC and CLP groups across all McNamara parameters. Non-cleft individuals exhibited greater maxillary length (Co-A: 88.21 ± 4.32 mm), mandibular length (Co-Gn: 119.35 ± 5.43 mm) and maxillomandibular dif-

**TABLE 4.** ANOVA for cleft types

| Parameter | Sum of squares | df | Mean square | F | Sig. |
|---|---|---|---|---|---|
| **Co-A** | | | | | |
| Between | 456.78 | 4 | 114.20 | 4.987 | 0.001 |
| Within | 2701.32 | 118 | 22.89 | | |
| Total | 3158.10 | 122 | | | |
| **Co-Gn** | | | | | |
| Between | 876.54 | 4 | 219.14 | 4.654 | 0.002 |
| Within | 5556.78 | 118 | 47.09 | | |
| Total | 6433.32 | 122 | | | |
| **MMD** | | | | | |
| Between | 312.45 | 4 | 78.11 | 3.876 | 0.005 |
| Within | 2378.92 | 118 | 20.16 | | |
| Total | 2691.37 | 122 | | | |

df: degrees of freedom; Co-A: maxillary length;
Co-Gn: mandibular length; MMD: maxillomandibular differential.

**TABLE 5.** Multiple comparisons (Tukey HSD) for MMD

| (I) Cleft type | (J) Cleft type | Mean difference (I-J) | SE | Sig. |
|---|---|---|---|---|
| NC | BCLP | 1.72* | 0.65 | 0.012 |
| NC | UCLP | 1.02 | 0.81 | 0.612 |
| NC | UCL | 0.98 | 0.92 | 0.723 |
| NC | UCLA | 1.92* | 0.98 | 0.041 |
| BCLP | UCLP | -0.70 | 0.81 | 0.876 |
| BCLP | UCL | -0.74 | 0.92 | 0.891 |
| BCLP | UCLA | 0.20 | 0.98 | 0.999 |
| UCLP | UCL | -0.04 | 1.03 | 1.000 |
| UCLP | UCLA | 0.90 | 1.08 | 0.892 |
| UCL | UCLA | 0.94 | 1.17 | 0.912 |

*The mean difference is significant at the 0.05 level.
MMD: maxillomandibular differential; SE: standard error;
NC: non-cleft; BCLP: bilateral cleft lip and palate;
UCLP: unilateral cleft lip and palate; UCL: unilateral cleft lip;
UCLA: unilateral cleft lip and alveolus.

ferential (MMD: 31.14 ± 3.21 mm) compared to CLP individuals (Co-A: 83.76 ± 5.01 mm; Co-Gn: 113.21 ± 6.54 mm; MMD: 29.45 ± 4.56 mm). These differences likely reflect the maxillary hypoplasia commonly observed in CLP patients due to the cleft defect and surgical interventions (20, 21). The reduced maxillary length in CLP patients is consistent with previous research indicating maxillary growth retardation following cleft repair surgeries (22).

Among cleft subtypes, ANOVA and post-hoc analyses revealed that NC individuals had significantly greater Co-A and Co-Gn measurements than BCLP and UCLA patients. The MMD was also significantly greater in NC individuals compared to BCLP and UCLA patients. These findings suggest that bilateral clefts and clefts involving the alveolus may have more pronounced effects on sagittal jaw development than unilateral clefts. The heterogeneity within CLP subtypes underscores the need for individualized treatment approaches based on specific cleft characteristics (23).

The utilization of AI-based cephalometric analysis in this study demonstrates the technology's value in efficiently processing large datasets and providing consistent measurements. The AI approach minimizes human error in landmark identification, enhancing the reliability of orthodontic assessments (4, 24). This methodological strength supports the validity of our findings.

Comparisons with previous research reveal both consistencies and distinctions. Our findings regarding reduced maxillary length in CLP patients align with the established literature (20, 21). However, the specific differences observed among cleft subtypes provide new insights into the differential impact of cleft type on craniofacial development. The reduced MMD in BCLP and UCLA patients suggests these groups may require more aggressive maxillary advancement interventions compared to other cleft types.

The clinical implications of our findings are substantial. The significant differences in McNamara parameters between NC and CLP groups, and among cleft subtypes, highlight the importance of cleft-specific considerations in orthodontic and surgical planning. Specifically, the reduced maxillary length and MMD in BCLP and UCLA patients suggest these groups may benefit from early maxillary protraction therapies. Orthodontists and surgeons should consider these variations when developing treatment protocols for different cleft types.

Limitations of this study include its cross-sectional design and the use of archival data. Future longitudinal studies tracking craniofacial changes over time would provide valuable insights into treatment outcomes. Additionally, incorporating three-dimensional imaging could enhance the assessment of complex craniofacial relationships in CLP patients. ❑

## CONCLUSIONS

This analysis of a comprehensive dataset revealed that, while gender does not significantly impact McNamara parameters, substantial differences exist between individuals with and without CLP, as well as among different cleft subtypes. The findings emphasize the importance of cleft-specific considerations in orthodontic and craniofacial treatment planning. The use of AI-based cephalometric analysis proved valuable in efficiently processing the dataset and providing reliable measurements. Future research should focus on longitudinal assessments and the integration of advanced imaging technologies to further refine treatment approaches for CLP patients. ❑

*Data availability: Data available from the first authors upon request.*
*Conflicts of interest: none declared.*
*Financial support: none declared.*

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