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Craniofacial Morphology in Skeletal Class I Patients with Severe Maxillary Anterior Crowding

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ABSTRACT

Background: Patients with severe maxillary anterior crowding usually present with ectopic eruption of canines and palatally displaced lateral incisors. **Objective:** The objective of this study is to find craniofacial morphology in patients with a skeletal Class I base exhibiting severe maxillary anterior crowding (MxAC). These morphological characteristics may serve as useful indicators for diagnosis and treatment planning, particularly in cases requiring extractions. **Study Design:** Retrospective cross sectional observational comparative study. **Settings:** Out Door Patient (OPD) department of Orthodontics, Allied Hospital, Faisalabad Medical University, Faisalabad Pakistan. **Duration:** Four months (April 2023 to August 2023). **Methods:** 35 individuals with normal occlusion (mean age: 20.7 ± 2.3 years) were included as the control group, and 35 patients with severe MxAC (mean age: 20.3 ± 3.8 years). Arch length discrepancy (ALD) was measured on dental casts. Six skeletal cephalometric parameters were recorded. Descriptive statistics, including means, standard deviations, medians, and interquartile ranges, were calculated for each variable. The nonparametric Mann-Whitney U test was used to compare the groups, with a $P < 0.05$ criterion for statistical significance. **Results:** Patients in the MxAC group showed a substantially larger saddle angle ($P < 0.05$), shorter anterior and posterior cranial base lengths ($P < 0.01$), and a shorter maxillary base length ($P < 0.01$) when compared to the control group. **Conclusion:** Patients with severe MxAC and skeletal Class I relationships exhibited unique craniofacial characteristics, including a shorter sagittal maxillary base, a broader cranial base angle, and shorter cranial base length.

Keywords: *Skeletal Class I, Sagittal maxillary base, Cranial base length, Saddle angle, Maxillary anterior crowding.*

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INTRODUCTION

Adult patients frequently seek orthodontic treatment with maxillary anterior crowding (MxAC) as their primary esthetic concern.[1] MxAC is typically characterized by labial displacement of the maxillary canines and palatal displacement of the maxillary lateral incisors. This malocclusion usually results from a discrepancy between relatively large tooth size and a reduced dental arch perimeter.[2,3] MxAC affects not only dental esthetics but also occlusion,[4] and it remains one of the main concerns among young orthodontic patients regarding smile esthetics.[5] In common language, such irregular alignment is often referred to as “fangs” or “snaggleteeth” in the United States.[5]

The etiology of ectopic eruption of maxillary canines and incisors has been widely investigated in relation to craniofacial morphology. Misa Akoma[6] reported a strong association between craniofacial anomalies and severe maxillary anterior crowding in women. Similarly, Arvind Sivakumar[7] compared craniofacial and malocclusion characteristics across different ethnic groups and found that skeletal Class II patterns were more common among South Indian than among Vietnamese adults with Class II malocclusion.

Larsen *et al*.[8] analyzed sagittal, vertical, and transverse dimensions of the maxilla in patients with ectopic maxillary canines using cephalometric and dental cast analyses. They observed that patients with ectopically erupted canines exhibited a transversely wider but sagittally and vertically deficient maxillary complex. Anterior crowding was reported to be more common among females than males.[9]

Sacerdoti and Baccetti[10] evaluated vertical craniofacial morphology in patients with palatally erupting canines and found a significantly higher ratio of low-angle skeletal patterns compared with control subjects. In contrast, Mucedero *et al*.[11] studied 49 patients with ectopically erupted canines and reported a higher prevalence of hyperdivergent skeletal patterns and narrower maxillary intercanine and intermolar widths compared with controls. They concluded that buccal displacement of maxillary and mandibular canines is more likely affected by local environmental factors, whereas palatal eruption is more closely linked to genetic determinants.[12]

Previous studies have basically focused only on the association between crowding in the anterior segment of the mandibular arch and cranial base morphology. Gong *et al.*[10] compared craniofacial characteristics between Class II and Class III patients, while Melo *et al*. observed a relatively shorter anterior cranial base length in patients with mandibular crowding compared with control groups in the deciduous dentition. T€urkkahraman and Sayin,[13] however, found no significant differences in cranial base angle or length between subjects with and without mandibular anterior crowding in early mixed dentition.

Until now, there is limited data available evaluating the association between severe maxillary anterior arch crowding in skeletal Class I individuals and cranial base morphology, particularly regarding sagittal maxillary base length (ANS-PNS). It is hypothesized that patients with a severely crowded anterior maxillary arch may exhibit a short maxillary base compared with those with Class I non-crowded arches.

Therefore, the purpose of this study was to investigate craniofacial morphology in skeletal Class I patients presenting with severe maxillary anterior crowding, characterized by ectopically labially erupted maxillary canines and palatally erupted lateral incisors.

METHODS

The study was conducted after obtaining ethical approval from the Ethical Review Committee (ERC) of Faisalabad Medical University, Faisalabad, Pakistan vide letter No. F.48-ERC/FMU/2022-23/280 Dated 08/06/2023 This study was carried out in the Out Door Patient (OPD) department of Orthodontics over the course of four months (April 2023 to August 2023), at Allied Hospital, Faisalabad Medical University, Faisalabad Pakistan.

This study was designed as a retrospective cross-sectional study. Power analysis indicated that a minimum of 18 subjects per group was required to detect an effect size with 80% power and a 5% significance level.

A total of 70 adult male and female patients (mean age: 20 years; range: 18–29 years) attending the orthodontic outpatient department were screened according to the following inclusion criteria:

1. No history of previous orthodontic treatment or congenital craniofacial anomalies (e.g., cleft lip or palate).
2. Straight facial profile without evident lip strain or hyperactivity of the mentalis muscle.
3. Presence of all permanent teeth with severe maxillary anterior crowding and a skeletal Class I relationship.
4. The absence of teeth with rotations, impactions, transpositions, aberrant crown morphology, or extended deciduous tooth retention.
5. Clinically healthy periodontal tissues without signs of gingivitis or periodontitis.

The objectives, methodology, and potential risks and benefits of the study were explained to all participants both verbally and in writing, and informed consent was taken.

Dental casts and lateral cephalograms were collected for all subjects. Arch length discrepancy (ALD) was calculated for each maxillary cast using a caliper. Subjects with an ALD greater than 8 mm were assigned to the severe crowding group (MxAC group), while those with an ALD less than 4 mm were assigned to the control group. All subjects demonstrated skeletal Class I relationships confirmed by an ANB angle of 2°–4° on cephalometric analysis.

All participants belonged to the same ethnic population (Faisalabad, Pakistan). The minimum age was set at 18 years to ensure completion of craniofacial growth.

Mesiodistal crown diameters of the maxillary central incisors, lateral incisors, canines, first and second premolars, and first molars were measured bilaterally using a digital caliper, divider, and millimeter ruler. Arch length discrepancies were calculated exclusively for the maxillary arch.

For both groups, statistical evaluations such as medians, interquartile ranges (IQRs), means, and standard deviations (SDs) were calculated.

Based on previous studies, six skeletal cephalometric measurements were recorded manually. Since the Articulare (Ar) point is thought to be a more authentic point than Basion (Ba), it was utilized as the posterior cranial base landmark in this study.[14]

These parameters were selected due to their established reliability in assessing cranial base morphology and its association with maxillary and mandibular skeletal relationships.

Table 1: Cephalometric measurements & their descriptions

Measurement	Description
Cranial base angle (Saddle angle)	The angle formed between the S–N plane and the S–Ar line.
Anterior cranial base length (S–N)	Linear distance between points **Sella (S)** and **Nasion (N)**.
Posterior cranial base length (S–Ar)	Linear distance between points **Sella (S)** and **Articulare (Ar)**.
Total cranial base length (N–Ar)	Linear distance between points **Nasion (N)** and **Articulare (Ar)**.
ANB angle	Angle formed between the lines connecting **N–A** and **N–B**, indicating the sagittal skeletal relationship between the maxilla and mandible.
ANS–PNS length	Linear distance between **Anterior Nasal Spine (ANS)** and **Posterior Nasal Spine (PNS)**, representing the sagittal length of the maxilla.

SPSS software (version 26.0; IBM Corp., Armonk, NY, USA) was used to enter and analyse all data. Each variable distribution was evaluated for normalcy using the Shapiro-Wilk test. If the data were not normally distributed, then nonparametric statistical techniques were applied. For cephalometric and dental parameters in control and maxillary anterior crowding groups, descriptive statistics such as means, medians, interquartile ranges (IQRs), and standard deviations (SDs) were computed. The skeletal and cranial base measurements were compared between the two groups using the Mann-Whitney U test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Table 2: Comparison of Cephalometric Measurements between the Control and MxAC Groups

Measurement	Control Group (n = 33)			MxAC Group (n = 33)			P value
	Median	Mean	SD	Median	Mean	SD	
Cranial base angle (°)	122	122	3.7	124	124	5.3	0.028
Anterior cranial base length (mm)	69	69	3.0	65	66	3.4	<0.001
Posterior cranial base length (mm)	39	38	3.8	35	34	3.4	<0.001
Total cranial base length (mm)	96	96	4.0	90	90	5.0	<0.001
ANB angle (°)	2	2	1.9	2	3	2.0	0.228 (ns)
ANS–PNS distance (mm)	48	48	2.0	45	45	3.0	<0.001

A total of 70 subjects were included in the analysis, comprising 35 patients with normal occlusion (control group) and 35 patients with severe maxillary anterior crowding (MxAC group). Both groups were matched for age, sex, and skeletal Class I relationships (ANB angle 2°–4°).

Descriptive statistics (median, mean, SD) and the results of intergroup comparisons using the Mann–Whitney U tests are presented in Table 2. ANB angle between the two groups (P = 0.228) was chosen to be same confirming that all participants exhibited a skeletal Class I relationship.

The saddle angle which is also called cranial base angle was found to be significantly greater in the MxAC group (124°) compared with the control group (122°) (P = 0.028). The total cranial base length (N–Ar) showed a significant reduction in the MxAC group compared with the control group (P < 0.001). Both anterior cranial base length (S–N) and posterior cranial base length (S–Ar) were significantly shorter in the MxAC group (P < 0.001).

The ANS to PNS distance which presents sagittal maxillary length, was also significantly shorter in the MxAC group (P < 0.001). Results show patients with severe anterior arch crowding have short maxillary base length.

Our study showed distinctive craniofacial morphological characteristics of severe crowding group compared with subjects with normal occlusion. Cranial base lengths were significantly shorter, cranial base angle was significantly wider and maxillary base length was shorter compared to control group.

DISCUSSION

In cases of severe maxillary anterior crowding (MxAC), the most common characteristics involves palatal displacement of the lateral incisors and buccal displacement of the canines. However, variations in this pattern may occur depending on individual growth characteristics and spatial limitations within the arch. In the present study, the focus was basically on the severity of maxillary anterior crowding, regardless of the specific pattern of tooth displacement.

In the Japanese language, the term “yaeba” refers to the appearance of multiple overlapping anterior teeth visible in the frontal smile, a feature that is sometimes perceived as attractive in certain cultures. Similar aesthetic tendencies have also been observed in the Italian population. The heritability of cranial base morphology may help explain ethnic variations in the direction and expression of maxillary canine displacement.[15] However, further multi-centre studies across diverse populations are required to clarify the influence of ethnic differences on cranial base morphology and the eruption path of ectopic maxillary canines.

In orthodontic research, the cranial base angle has long been recognized as an important morphologic parameter for understanding skeletal pattern differences among Angle’s classifications of malocclusion.[16] Variations in Saddle angle influences the spatial position and relationship of both the maxilla and mandible, thereby affecting both sagittal and vertical jaw relationships. The wider cranial base angle and shorter cranial base lengths observed in our patients with severe MxAC may suggest an underlying craniofacial structural predisposing factor contributing to anterior arch crowding.

According to previous studies have demonstrated that variations in the cranial base angle and lengths play a key role in determining the position of the condyle relative to the cranial base. A larger cranial base angle is typically associated with a more posteriorly positioned mandible (skeletal Class II pattern), whereas a smaller angle corresponds to a more anteriorly positioned mandible (skeletal Class III pattern).[17] However, only a limited number of investigations have examined the relationship between the cranial base angle and maxillary anterior crowding in patients with a skeletal Class I relationship.

In my study, the MxAC group exhibited a significantly wider cranial base angle compared with the control group, even both groups maintaining a Class I skeletal relationship. Our results correlate with one of previous research conducted in Class I patients,[18] suggesting that even within skeletal harmony, cranial base morphology may influence dental arch crowding. These results highlight a potential topographic correspondence between cephalometric measurements and spatial orientation of cranial reference points.[19]

The cranial base, maxilla, mandible, dental arches and dentition are anatomically and developmentally interconnected structures, particularly during the embryonic, prenatal and postnatal growth periods. That's why, alterations in cranial base morphology can influence the developmental configuration of both jaws and dental arches, predisposing certain individuals to maxillary anterior crowding. However, the precise biologic mechanisms underlying this association remain unclear and emphasize further longitudinal studies in growing individuals.

Larsen *et al*.[5] reported that children presenting with facially or palatally impacted maxillary canines requiring surgical exposure exhibited a shorter anterior cranial base length (approximately 1 mm) compared with controls. This reduction was not necessarily a consequence of anterior crowding but appeared to be part of a broader craniofacial structural pattern.

Although our sample consisted of adult subjects, we observed a greater difference in anterior cranial base length between the MxAC and control groups than that reported in studies on growing children. Moreover, both posterior cranial base length and total cranial base length were found to be significantly shorter in the MxAC group, further supporting the concept that cranial base morphology may contribute to the spatial limitations leading to anterior dental crowding in otherwise Class I individuals

The MxAC group demonstrated a significantly shorter anterior cranial base length and reduced anteroposterior maxillary dimension (ANS-PNS distance) compared with the control group. Our findings support with a recent review suggesting that the anterior cranial base length exerts a stronger influence on facial growth than the posterior cranial base length.[20] Although the relationship between cranial base morphology and cleft lip and palate patients remains uncertain,[28] it is plausible that post-surgical maxillary alterations in patients with a history of cleft palate repair affect maxillary growth without significantly affecting the cranial base morphology.

Furthermore, research indicates that rapid maxillary expansion (RME) in children aged 8 to 11 years results in limited expansion of the spheno-occipital synchondrosis,[21] suggesting that orthodontic intervention for arch length discrepancies in severe MxAC cases may have restricted skeletal effects, even during the growth period.

A shorter posterior cranial base length and an obtuse saddle angle positions the glenoid fossa and condyle more superiorly, actually contributing to an increased anterior facial height.[22] In our study, the MxAC group exhibited smaller sagittal and vertical maxillary dimensions (as indicated by ANS-PNS distance), which is definitely a defining feature of MxAC which can contribute to reduced dental arch proportions.

Forster *et al*.[22] observed that patients with hyperdivergent facial patterns(dolichofacial) tend to have narrower dental arches, likely due to lower masseteric muscular activity and reduced transverse and sagittal mandibular growth. However, numerous twin studies have demonstrated a strong genetic influence on cranial base development. Crowding in lower anterior arch might be due to pressure from 3rd Molar pressure.[22,23] This suggests that genetic factors, in combination with environmental factors, contribute to cranial base dysmorphology, afterwards impacting maxillary underdevelopment and indirectly predisposing individuals to MxAC.

Currently, treatment options for MxAC remain limited. In clinical practice, maxillary arch expansion during the mixed dentition and premolar extractions in the permanent dentition are the most employed approaches. As hypothesized by Enlow and Hans[24] and further supported by Klocke *et al*., the morphology and dimensions of the cranial base are largely determined by five years of age. Therefore, the presence of a greater cranial base angle, shorter anterior and posterior cranial base lengths, and wider mesiodistal dimensions of maxillary central incisors identified in early mixed dentition may serve as predictive indicators of MxAC.

Clinically, these findings suggest that interceptive Orthodontics may play a major role in reduction of future developing anterior arch crowding. In Class I MxAC patients, maxillary expansion and serial extraction strategies could be more effective for long-term management. Furthermore, the greater arch length discrepancy, displacement of lateral incisors and canines, smaller dental arch dimensions, and labially proclined maxillary central incisors are salient features of the MxAC group reinforce the potential necessity of premolar extractions with maximum anchorage control to achieve more stable orthodontic results.[25]

CONCLUSION

Patients with skeletal Class I and severe maxillary anterior crowding (MxAC) revealed:

- A significantly wider cranial base(saddle) angle,
- Shorter anterior, posterior, and total cranial base lengths
- Smaller sagittal maxillary bases length (ANS-PNS distance)

These findings demonstrate that cranial base morphology may play a significant role in the etiology of maxillary anterior crowding, even among individuals with skeletal Class I patterns. Understanding these craniofacial relationships can encourage clinicians in early diagnosis, treatment planning, and predicting the response to orthodontic interventions in patients with MxAC.

Conclusion: Patients with severe MxAC and skeletal Class I relationships showed shorter sagittal maxillary base, a broader cranial base angle, and shorter cranial base lengths.

SHORTCOMINGS / LIMITATIONS

The study relies on lateral cephalograms, which are two-dimensional which may not accurately capture complex 3D craniofacial structures. 3D imaging (e.g., CBCT) techniques would provide more precise data. Additionally, a single-institution sample limits the generalizability of the results.

SUGGESTIONS / RECOMMENDATIONS

Patients with Class II and Class III skeletal relationships can also be included to determine whether similar craniofacial patterns exist across different malocclusions. Future multicentre studies approach with larger samples and longer follow-up periods could offer more comprehensive insights.

CONFLICT OF INTEREST / DISCLOSURE

There is no conflict of interest related to the conduct or publication of this study. No financial or personal relationships influenced the research outcomes.

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No.

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