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Research Article

Relationship between Maxillary Occlusal Plane Inclination and Soft Tissue Harmony in Adults with Different Sagittal Skeletal Malocclusions

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Abstract
A harmonious soft tissue profile, as an important treatment goal in orthodontics, is sometimes difficult to achieve, partly because the soft tissue overlying the teeth and bones is highly variable in its thickness. These variations result not only from imbalance of the dental and skeletal structures but from individual variations in the thickness and tension of the soft tissues.

Objective: To investigate the relationship between maxillary occlusal plane inclination and soft tissue harmony of the face in different sagittal skeletal malocclusions.

Material and Methods: The study was a cross-sectional observational study. Lateral cephalometric x-rays of 160 individuals were collected from the Orthodontic clinic at the Faculty of Dentistry, Beirut Arab University and divided into 4 equal groups based on ANB as a parameter of intermaxillary skeletal relationship: Class I (CI) ($0 \leq$ ANB ≤ 4), Class II division 1 (CII div 1) (ANB > 4 with normal or proclined upper incisors), Class II div 2 (CII div 2) (ANB > 4 with retroclined upper incisors) and Class III (CIII) (ANB < 0).

Hard tissue analysis included 1 angular measurement for maxillary occlusal plane (MxOP) inclination. Soft tissue analysis included 2 angular measurements for facial convexity and 3 linear measurements for inter-jaw harmony and 7 linear measurements for soft tissue thickness.

Results: There was significant correlation between MxOP angle and facial contour angle, as well as Sn-Pog′ for participants with CI. In CII div 1, there was a significant correlation between MxOP angle and ULA-LLA, as well as chin thickness V. In CII div 2, there was a significant correlation between MxOP angle and Sn-Pog′, ULA-LLA, upper lip strain, chin thickness H, and chin thickness V. In class III, there was no significant correlation.

Conclusion: H angle, facial contour angle, inter-jaw harmony and soft tissue thickness parameters were not always correlated with MxOP angle and this correlation was highly variable between different skeletal malocclusions. Therefore one cannot fully support the existence of a relation between MxOP and soft tissue harmony.

Keywords
Maxillary occlusal plane - Soft tissue harmony - Soft tissue thickness - Sagittal skeletal malocclusion.

Declaration of Conflicting Interest

The author[s] declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Introduction

Early in the history of orthodontics, both clinicians and researchers were aware of the relevance of the occlusal plane in the diagnosis and treatment of malocclusions (Coro et al., 2016). Aesthetically and functionally, occlusal plane inclination is considered as an important factor in orthodontic treatment.

On the frontal view, the occlusal plane inclination is one of the parameters affecting smile esthetics, and can be attributed to the right and left skeletal and/or dental arch asymmetry (Senisik and Hasipek, 2015). A previous study reported that the occlusal plane inclination on the sagittal plane is a factor that reflects an acquired harmonious relationship between cranio-mandibular configuration and function (Ogawa et al., 1998). However, smile dynamics are complex, and multiple factors must be considered when objectively evaluating a patient's smile (Kattadiyil et al., 2012).

Functional aspects are related to the position of the occlusal plane is one of many such critical factors; therefore, the dental professionals should harmonize dental, skeletal and soft tissue structures of the masticatory system (Ogawa et al., 1996; 1998; Sato et al., 2007). The form and inclination of the occlusal plane (OP) hold individual characteristics and are connected not only with the function of the stomatognathic system but also with the esthetics of dentofacial appearance. A functional correlation between the inclination of OP and the masticatory closing path has been observed. This is an important determinant in occlusion and one of the contributing factors to masticatory movement (Ogawa et al., 1998).

The upper smile arc is the relationship of the curvature of the maxillary incisal and canine edges to the curvature of the lower lip during the social smile which is influenced by the OP angle. A report by Batwa et al. (2012) demonstrated that large alterations in the occlusal plane inclination has an effect on smile attractiveness. Smiles with occlusal planes at 10º to true horizontal were deemed most attractive by patients. In the lateral aspect, the inclination of the OP can also influence the extent of sagittal malocclusions, namely by the magnitude of the curve of Spee and OP rotation (Farella et al., 2002).

The inclination of the maxillary posterior occlusal plane during growth and development can influence skeletal pattern and malocclusion type. There is potential differential maxillary and mandibular skeletal growth expressed along the OP (Braun and Legan, 1997). Casko and Shepherd (1984) noted that as the ANB angle increased, the inclination of the OP likewise increased.

The interrelationship between the soft tissue profile and the underlying skeletal pattern has been reported by many researchers, but this issue still remains controversial. Riedel (1950; 1957) stated that there are strong interconnections between the skeletal pattern and the soft tissue profile, whereas others have suggested that the soft tissue profile was not matched to the skeletal pattern because of the variations of individual factors (Burstone, 1958; Subtelny, 1959; Park and Burstone, 1986).

The aim of the study to investigate the relationship between maxillary occlusal plane inclination and soft tissue harmony of the face in different sagittal skeletal malocclusions.

Materials and Methods

The study design is cross-sectional, observational study and was conducted at the Faculty of Dentistry, Beirut Arab University.

Sample size estimation was performed using 80% power of the study using OpenEpi, Version 3, open source calculator (Dean, Sullivan and Soe, 2017) at alpha= 0.05. This yielded to a sample size of 160 lateral cephalometric x-rays, divided into 4 main groups of 40 each according to their sagittal skeletal relationships:

- Group 1 for Class I malocclusion: Subjects having an ANB angle between 0º and 4º.
- Group 2 for Class II division 1 malocclusion: Subjects having an ANB angle > 4º with normal or proclined upper incisors.
- Group 3 for Class II division 2 malocclusion: Subjects having an ANB angle > 4º with retroclined upper incisors.
- Group 4 for Class III malocclusion: Subjects having an ANB angle < 0º.

Inclusion criteria included subjects satisfying the following:

- Aged between18 and 45 years old.
- Normal vertical relationship with an SN-MP angle = 32º + 2.
- All teeth are present with or without the presence of third molars.

Exclusion criteria included subjects:

- Having previous orthodontic treatment or orthognathic surgery.
- With systemic diseases and cranio-facial anomaly.
- Having traumatic injuries.
- Who had received facial esthetic treatment including Botox and fillers.

Ethical approval code (2020-H-0108-D-M-0383) was obtained from the ethical board (IRB) of Beirut Arab University before beginning the study.

Methods

All lateral cephalometric x-rays were taken by the same operator using the same machine (X-ray device, Kodak 9000 3D, Carestream Health, Inc., Rochester, NY, USA) and under the same technical conditions. The patient was standing, head fixed in a way that the sagittal plane was at the right angle to the path of the x-rays and the Frankfort Horizontal Plane (FHP) was parallel to the horizontal plane. Teeth were occluded in centric occlusion and lips were maintained in relaxed position.

One hundred and sixty lateral cephalometric radiographs were traced and analyzed using Adobe Photoshop CC program (2018 Version 20.0). Magnification was recorded for each cephalometric head film and the readings were adjusted accordingly. Hard and soft tissue landmarks were defined **(Table 1)** and all cephalometric landmarks were determined according to the definition of Broadbent 1975, Jacobson 2006 and Phulari, 2013. The tracings were completed and the variables measured in millimeters or degrees.

Hard Tissue Landmarks	Soft Tissue Landmarks
Point A (A)	Soft tissue point A (A')
Point B (B)	Upper lip anterior (ULA)
Upper incisor tip (Mx1)	Lower lip anterior (LLA)
Upper molar cusp tip (Mct)	Soft tissue point B (B')
Upper incisor (U1)	Soft tissue Pogonion (Pog')
Lower incisor (L1)	Soft tissue Menton (Me')
Pogonion (Pog)	Glabella (G')
Nasion (N)	Labiale superius (Ls)
Sella (S)	Labiale inferius (Li)
Menton (Me)	Soft tissue Nasion (Na)
	Soft tissue point A (A')

Table 1 Hard and soft tissue landmarks

Cephalometric Measurements

The cephalometric xrays were adjusted according to the natural head position, by adding 5.6° to S-N inclination (Lundström, 1992). Three angular measurements, consisting of maxillary occlusal plane (MxOP) angle, H angle and facial contour angle were defined **(Table 2) (Figure 1)**, as well as linear measurements of inter-jaw harmony and lower facial soft tissue thickness (Table 3) (Figure 2).

Maxillary occlusal plane angle (MxOP)	Angle that formed between maxillary occlusal plane and TVL
H angle	Angle that formed between Harmony line (H-line) and soft tissue facial plane
Facial contour angle	Angle formed between the lower and upper facial contour planes above (Sn)

Table 2 Angular measurements.

Statistical Analyses

Statistical analyses of the data were performed using the SPSS for Windows (Chicago, IL, USA, version 25.0). The level of significance level is set at $p \leq 0.05$.

Kolmogorov-Smirnov tests were executed to assess the normality distribution of the continuous variables. Parametric tests were performed for variables normally distributed. Non-parametric tests were performed for variables not normally distributed. Student t tests and Mann-Whitney tests were used for the comparison MxOP angle, H angle, facial contour angle, inter-jaw harmony and soft tissue thickness for each sagittal skeletal malocclusion.

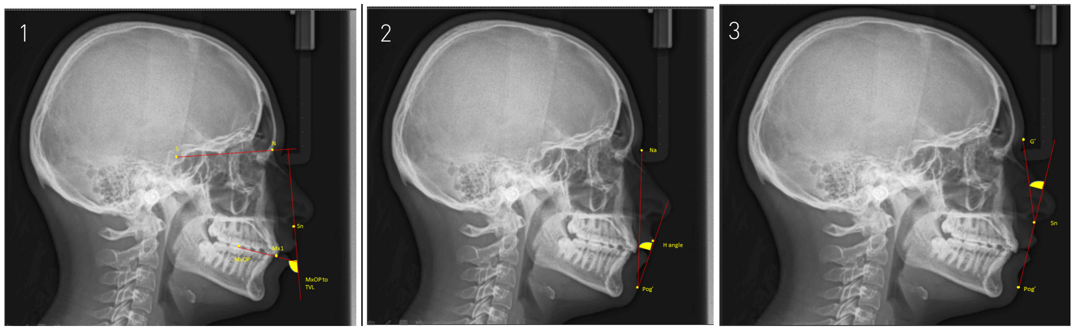

Figure 1 Angular measurements: (1) Maxillary occlusal plane angle (MxOP), (2) H angle and (3) Facial contour angle.

Inter-jaw harmony (Arnett ,1999)	
Sn'-Pog'	Linear distance from the base of the soft tissue maxilla (Sn') to soft tissue chin (Pog')
A'-B'	Linear distance from soft tissue A' to soft tissue B'
ULA-LLA	Linear distance from upper lip anterior to lower lip anterior
Lower facial soft tissue thickness (Holdaway, 1983)	
Basic upper lip thickness	Linear distance from 3 mm below A-point to Subnasale
Upper lip thickness	linear distance from the most prominent labial point of the maxillary incisor (U1) to labrale superius (Ls)
Upper lip strain	Difference between basic upper lip thickness and upper lip thickness
Basic lower lip thickness	linear distance from B-point to the deepest point of the labiomental fold
Lower lip thickness	linear distance from the most prominent labial point of the mandibular incisor (L1) to labrale inferius (Li)
Chin thickness-H	Linear distance from Pogonion to its sagittal projection on the soft tissue (Pog-Pog')
Chin thickness-V	Linear distance from Menton to its vertical projection on the soft tissue (Me-Me')

Table 3 Linear measurements.

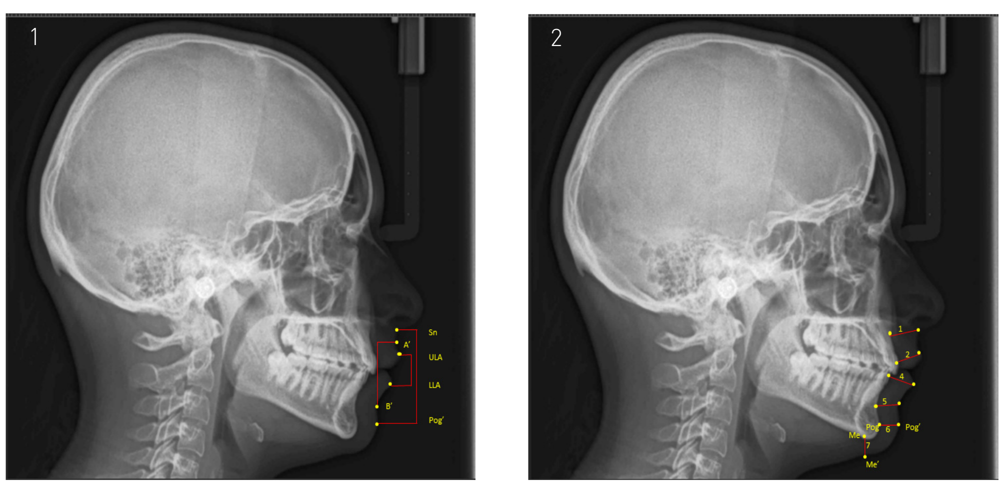

Figure 2 Linear measurements: (1) Inter-jaw harmony and (2) Lower facial soft tissue thickness

The correlation between MxOP angle, H angle, facial contour angle, inter-jaw harmony and soft tissue thickness parameters were investigated using Pearson correlation coefficient; preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. When assumptions are violated, Spearman correlation coefficients were obtained for the correlation. Interpretation of the correlation coefficient is achieved according to Cohen (1988). Hence, a correlation coefficient r=0.10 to 0.29 is considered small, a correlation coefficient r=0.30 to 0.49 is considered medium and a correlation coefficient r = 0.50 to 1.00 is considered large.

Reliability of the Measurements

Intra-observer reliability in measurement of the parameters was determined using the Dahlberg (1940) formula:

$$S_D = \sqrt{\frac{\sum_{i=1}^{N} d_i^2}{2N}}$$

The reproducibility of measurements was assessed twice on a sample of 20 subjects using the intra-class correlation coefficient (ICC). The ICC were superior than 0.990 indicating an excellent reproducibility.

Results

All results obtained figure in Table 4. It can be summarized as follows:

• There was a positive moderate correlation between MxOP angle and facial contour angle for participants with Class I (r=0.320; p=0.044).

• There was a negative correlation between MxOP angle and Sn-Pog'. It was moderate for participants with Class I (r=-0.325; p=0.041).

• The correlation between MxOP angle and ULA-LLA was positive and moderate for participants with Class II division 1 (r=0.373; p=0.018).

• There was a negative moderate correlation between MxOP angle and chin thickness V for participants with Class II division 1 (r=-0.415; p=0.018).

• There was a negative moderate correlation between MxOP angle and Sn-Pog' for participants with Class II division 2 (r=-0.367; p=0.020).

• The negative correlation between MxOP angle and upper lip strain was moderate for participants with Class II division 2 (r=-0.483; p=0.002).

• There was a negative moderate correlation between MxOP angle and chin thickness V for participants with Class II division 2 (r=-0.323; p=0.042).

• There was no significant correlation between MxOP angle and inter-jaw harmony or soft tissue thickness parameters in participants with Class III (-p-value>0.05).

		MxOP angles			
		CI	CII div1	CII div2	CIII
H angle	Correlation coefficient -p-value N	-0.079 0.626 40	0.221 0.170 40	-0.004 0.981 40	-0.031 0.848 40
Facial contour angle	Correlation coefficient -p-value N	0.320* 0.044 40	0.289 0.070 40	-0.123 0.450 40	0.142 0.382 40
Sn-Pog'	Correlation coefficient -p-value N	-0.325 0.041 40	-0.300 0.060 40	-0.367* 0.020 40	0.070 0.667 40
A'-B'	Correlation coefficient -p-value N	-0.061 0.710 40	-0.243 0.130 40	-0.256 0.110 40	-0.045 0.783 40

ULA-LLA	Correlation coefficient -p-value N	0.198 0.220 40	0.373* 0.018 40	-0.082 0.616 40	-0.114 0.484 40
Basic upper lip thickness	Correlation coefficient -p-value N	-0.089 0.584 40	-0.256 0.111 40	-0.110 0.498 40	-0.204 0.208 40
Upper lip Thickness	Correlation coefficient -p-value N	-0.115 0.482 40	-0.088 0.591 40	0.062 0.704 40	-0.089 0.586 40
Upper lip strain	Correlation coefficient -p-value N	0.044 0.789 40	-0.244 0.129 40	-0.483* 0.002 40	-0.155 0.340 40
Lower lip thickness	Correlation coefficient -p-value N	-0.142 0.382 40	-0.027 0.868 40	-0.143 0.378 40	-0.130 0.423 40
Basic lower lip thickness	Correlation coefficient -p-value N	-0.132 0.417 40	-0.249 0.122 40	-0.302 0.058 40	0.022 0.892 40
Chin thickness H	Correlation coefficient -p-value N	-0.121 0.455 40	-0.283 0.077 40	-0.307 0.054 40	-0.073 0.656 40
Chin thickness V	Correlation coefficient -p-value N	-0.290 0.069 40	-0.415* 0.018 40	-0.323* 0.042 40	-0.051 0.752 40

** Statistically significant at p < .05*

Table 4 Pearson's test for the correlation between MxOP angle, H angle, Facial contour angle, inter-jaw harmony and soft tissue thickness parameters in participants with Class I, Class II division1, Class II division 2 and CIII.

Discussion

The aim of the study was to investigate the relationship between maxillary occlusal plane inclination and soft tissue harmony of the face in different sagittal skeletal malocclusions. Skeletal and soft tissue parameters were evaluated by cephalometric measurements.

The correlation between MxOP angle and facial contour angle was positive in class I sample. Mayne (1946), used an angle which differs from the facial contour angle used in the presents study in that gnathion is slightly posterior to pogonion. A test, of ten cases showed that, this made an average difference of -1.25° in readings; therefore this amount has been added to Mayne's findings to make them comparable to the facial angle. The other angles compared; mandibular plane angle and cant of occlusal plan were recorded. The angular relation between the occlusal plane and the Frankfort plane in the control series ranged from +14° to 1.5° with a mean of +9.3°. A coefficient of correlation of -0.775 between this plane and the facial angle indicated that there was a tendency for the planes to approach parallelism as the facial angle increased. Generally speaking the Class II facial types have a relatively steep occlusal plane. As the facial type approaches the class III pattern the occlusal plane tends to become more horizontal.

The present study also showed a negative correlation between MxOP angle and Sn-Pog' for participants with Class I. An explanation for this might be due to a steepening of the maxillary occlusal plane inclination related to the posterior rotation of the mandibular plane and leads to increase in the anterior facial height (AFH) and the soft tissue facial heights increase likewise in hyperdivergent growth subjects and affect the inter-jaw harmony which support Björk (1969) findings. However, there is no correlation between MxOP angle and A'-B', Also there is no correlation between MxOP angle and ULA-LLA.

According to Björk (1969) forward mandibular rotation occurs when posterior facial height (PFH) overdevelops relative to AFH; however, in many literature sources more attention was focused on the AFH and lower AFH has been confirmed as having a strong influence on the formation of vertical facial disproportions (Sassouni, 1958; Sassouni, 1964; Subtelny, 1964).

In the present study the correlation between MxOP angle and ULA-LLA was positive in class II division 1 sample, the positive correlation between MxOP angle and ULA-LLA suggests that if the MxOP angle increased, ULA-LLA also increase. An explanation for this might be due to a steepening of the maxillary occlusal plane inclination will increase the vertical distance between upper and lower lips due to vertical dimension increase in hyperdivergent facial type and affect the inter-jaw harmony. The change in the inclination of the OP can alter the mandibular position relative to the maxillary occlusal surfaces as well as the condylar adaptive response to it, which plays a key role in the establishment of different dentoskeletal frames (Tanaka and Sato, 2008). However, there is no correlation between MxOP angle and A'-B', Also there is no correlation between MxOP angle and Sn-Pog' in Class II division 1 sample.

The present study also showed a negative correlation between MxOP angle and Sn-Pog' for participants with Class II division 2. which is in agreement with results concluded by Holly, (2012), in which steepening of the maxillary occlusal plane inclination affect the inter-jaw harmony and the distance between Sn-Pog' decrease. Subjects with Class II division 2 malocclusion have a different lip shape, position, and thicker lips as identified by Mclyntyre, (2006). Thicker lips appear to respond less to incisor movement and provide better support to lip morphology (Alkadhi et al., 2019). This might explain the significance in the correlation between the maxillary occlusal plane and Sn-Pog'.

Moreover, there was a negative correlation between MxOP angle and upper lip strain. Holdaway (1983) suggested that 1 mm or less of upper lip strain would be acceptable, and an excessive amount would indicate thinning of the upper lip as it is stretched over the protrusive teeth. Therefore, acceptable upper lip strain could be established by controlling the incisors to eliminate lip strain. From the correlation results by Lee et al., (2015) , upper lip strain was statistically correlated with U1 to NA (degrees and millimetres), U1 to SN (degrees), and overjet positively and was influenced by the inclination and anteroposterior position of the maxillary incisors, which gives the explanation that the more retroclined the upper incisors and steeping the maxillary occlusal plane the thicker is the upper lip and less upper lip strain, in other words the soft tissue might be trying to compensate for underlying skeletal malocclusion.

According to Schudy (1964) and Isaacson et al. (1971), the degree of inclination of the mandible to the cranial base (SN-MP) has an effect on mandibular rotation, the larger the SN-MP angle, the more the mandible tends to become steeper and the more the chin moves backward, and vice versa. Therefore, we assumed that the characteristics of soft tissue measurements would be variable even in the same skeletal class if accompanied by a different vertical pattern. The negative correlation between the MxOP angle and chin thickness V suggested that the perioral soft tissues would be stretched to compensate for the incremental difference between the soft and hard tissue contours, resulting in reduced thickness. Comparison with other studies was inconsistent as there is no published study the MxOP angle with chin thickness V in class II div 2.

In the present study, the correlations of the soft and hard tissue parameters in class III results showed that there was no significant correlation between soft tissue parameters with maxillary occlusal plane angle.

Conclusion

Within the limitation of this study, the following conclusions can be drawn:

• H angle, facial contour angle, inter-jaw harmony and soft tissue thickness parameters were not always correlated with maxillary occlusal plane angle and this correlation was highly variable between different skeletal malocclusions.

• Many factors affect soft tissue harmony, therefore one cannot fully comprehend its correlation with maxillary occlusal plane angle.

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