

Orthodontic Treatment Planning: Do Orthodontists Treat to Cephalometric Norms?

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Abstract

Cephalometric norms are important to orthodontists in their diagnosis, treatment, and evaluation of orthodontic treatment outcomes. The purpose of the present study is to establish if orthodontists treat and finish their cases to the cephalometric means or norms.

Pre- and post-cephalometric radiographs and dental casts of 35 orthodontically treated cases were analyzed. The Kappa test, Wilcoxon Signed-Rank test, Paired t- test, and Z-test were used for the statistical analysis of the data. The result revealed that orthodontists do not reach the cephalometric mean values post-treatment. However, sagittal maxillomandibular relationship and interlabial gap are the main areas of improvements. This leads to improvement of soft tissue esthetics by camouflaging the skeletal and dental relationship.

Keywords: Orthodontics, cephalometric variables, cephalometric tracings

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Introduction

In orthodontics, cephalometric variables are angular and linear measurements. Those cephalometric measurements or norms consist of mean values with their statistical standard deviation.

Orthodontists use the values of those measurements or norms for their diagnosis, treatment, and assessment of orthodontic treatment outcomes.^{1,2,3} In diagnosis, the patient's cephalometric measurements are compared to the related norms in order to establish the amount of deviation or malrelationship. In treatment, orthodontists utilize these norms as their guidance towards their treatment goals. In assessing the success of the orthodontic treatment or treatment outcome, orthodontists usually compare the changes between post- and pre-treatment measurements in comparison to the norms. However, many of the cephalometric mean values have large standard deviations. This may lead to the inability to interpret the cephalometric clinical data properly. Therefore, from a clinical and practical point of view, orthodontists appear to utilize the cephalometric mean values without their standard deviation as the norms and then use the related standard deviation to indicate the tendency or slight deviation from normality. The aim of the present study is to evaluate if orthodontists are actually treating to the mean values as their cephalometric norms.

Material and Methods

The sample of the present study consists of pre- and post-orthodontic lateral cephalographs of 35 completed orthodontic cases selected randomly. The cases were selected on the basis of the following criteria:

1. Orthodontic treatment was done using fixed appliances without including orthognathic surgical cases.
2. Good quality, pre- and post-treatment lateral cephalometric radiographs were taken with lips at repose.

The same standardized cephalometric machine was utilized to obtain all pre- and post-treatment lateral cephalometric radiographs. Pre- and post-treatment lateral cephalometric radiographs were traced; then selected skeletal, dental, and soft tissue landmarks were identified (Figure 1).

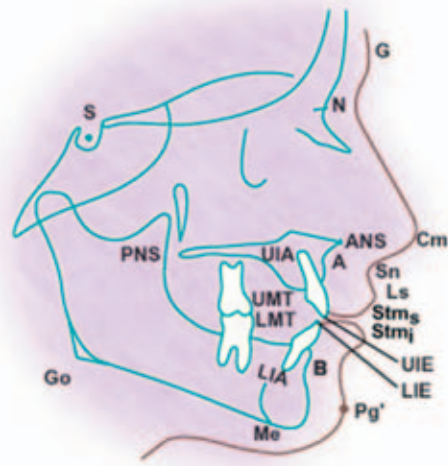


Figure 1. Skeletal, dental and soft tissue landmarks.

The following variables were used to represent horizontal and vertical relationships for skeletal, dental, and soft tissues:

Skeletal:

Horizontal:

- SNA - (Indicates the anteroposterior position of maxillary apical base in relation to cranial base.)
- SNB - (Indicates the anteroposterior position of the mandible apical base in relation to the cranial base.)
- ANB - (Indicates the anteroposterior apical base relation of mandible to Maxilla.)

Vertical:

- PP/SN - (The angle between the palatal plane and anterior cranial base.)
- MP/SN - (The angle between the mandibular plane and anterior cranial base.)
- PP/MP - (The angle between the palatal plane and mandibular plane.)

Dental:

Horizontal:

- UIA – UIE / LIE- LIA - (The interincisal angle formed by the long axis of the upper and lower central incisors.)
- UIE – UIA / PP - (The angle formed by the long axis of the upper central incisor and palatal plane.)
- LIE – LIA / MP - (The angle formed by the long axis of the lower central incisor and the mandibular plane.)

Vertical:

UMT ⊥ PP (mm) - (The distance in millimeters from the upper molar mesial cusp tip perpendicular to palatal plane.)

UIE ⊥ PP (mm) - (The distance in millimeter from the tip of the upper central incisor perpendicular to palatal plane.)

LMT ⊥ MP (mm) - (The distance in millimeter from the lower molar mesial cusp tip perpendicular to mandibular plane.)

LIE ⊥ MP (mm) - (The distance in millimeter from the tip of the lower central incisor perpendicular to mandibular plane.)

Soft Tissue:

Horizontal:

G-Sn-Pg' (The angle of facial convexity)

Cm-Sn-Ls (The nasiolabial angle)

Vertical:

UIE – Stm_s mm (The upper incisor exposure)

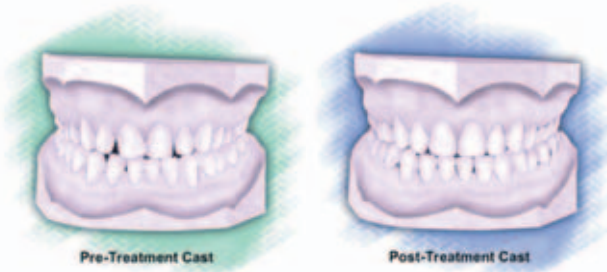
Stm_s – Stm_i mm (The interlabial gap)

The magnification factor for linear measurements was corrected by utilizing the magnification factor formula⁴ and was found to be 9.67.

PAR Index

To assess the orthodontic treatment result, the 35 orthodontic pre and post-treatment casts were evaluated. The Peer Assessment Rating (PAR) index was used. Richmond⁵ proposed criteria for orthodontic treatment to be considered of a high standard. These criteria include the following:

- The mean percentage reduction should be greater than 70%.
- The number of cases allocated to the “worse or no different” group should be negligible.
- The number allocated to “greatly improved” was greater than 40%.



Error of the Method

The variables of each case were measured in both pre- and post-treatment cephalograms and compared to the modified acceptable range (AR) of the present study. This modified AR was formed by the mean ± 1 – either degree or mm depending on the variable – rather than the mean ± one standard deviation as it had been used by others.⁶ The means for skeletal and dental variables were derived from the Michigan Growth Study.⁷ However, the means for soft tissue variables were derived from Legan and Burstone.⁸

The pre and post-treatment radiographs of 10 cases were randomly selected and traced by the investigator on two occasions with a period of 6 week intervals.

Statistical Analysis

To evaluate the presence of any significant difference between improved and worsened groups, the Z- test was used. On the other hand, the Wilcoxon Signed-Rank test was performed to evaluate the presence of a significant difference between the PAR index reading before and after treatment. The intra -examiner reliability was evaluated by using the Paired t-test, Dahlberg’s method⁹, and Pearson’s correlation coefficient test.¹⁰ In addition, the Kappa test was applied to assess the reliability of the PAR index. The 5% level of significance was designated in all the

Results

Intra-examiner Reliability

Pearson’s correlation coefficient revealed high reliability with r-values ranging between 0.978 to 0.998, and all corresponding P-values were below 0.05. Table 1 shows the percentage distribution of pre- and post-treatment skeletal changes in relation to the AR. Table 2 shows the percentage distribution of pre- and post-treatment dental changes in relation to the AR. Table 3 shows the percentage distribution of pre- and post-treatment soft tissue changes in relation to the AR.

The result of the Kappa test revealed the readings were between 0.83 and 1.00. This indicates almost perfect agreement. The PAR index result revealed only one case (2.9%) was found in the “worse or no different” (which is considered negligible) group. Fifteen cases (42.9%) were in the

Table 1. The percentage distribution of pre- and post-treatment skeletal changes in relation to the acceptable range (AR).

Skeletal Variable		SNA	SNB	ANB	PP/SN	MP/SN	PP/MP
Pre-treatment	<AR	51.4%	68.6%	17.1%	17.1%	11.4%	14.3%
	AR	17.1%	8.6%	22.9%	26.7%	2.9%	2.9%
	>AR	31.4%	22.9%	60%	57.1%	85.7%	82.9%
Post-Treatment	<AR	48.6%	68.6%	11.4%	11.4%	11.4%	8.9%
	AR	22.9%	11.4%	42.9%	34.3%	5.7%	2.9%
	>AR	28.6%	20%	45.7%	54.3%	82.9%	88.6%

Table 2. The percentage distribution of pre- and post-treatment dental changes in relation to the acceptable range (AR).

Dental Variable		UIA-UIE/ LIE-LIA	UIE-UIA/ PP	LIE-LIA/ MP	UMT ⊥ PP MM	UIE ⊥ PP MM	LMT_MP MM	LIE_MP MM
Pre-treatment	<AR	85.7%	11.4%	17.2%	25.7	8.6%	40%	17.1%
	AR	2.9%	8.6%	20%	22.9%	31.4%	22.9%	25.7%
	>AR	11.4%	80%	62.8%	51.4%	60%	37.1%	57.2%
Post-Treatment	<AR	71.4%	40%	28.6%	5.7%	11.4%	17.1%	25.7%
	AR	5.7%	17.1%	20%	37.1%	22.9%	37.1%	20%
	>AR	22.9%	42.9%	51.4%	57.2%	65.7%	45.7%	54.3%

Table 3. The percentage distribution of pre- and post-treatment soft tissue changes in relation to the acceptable range (AR).

Soft tissue variables		G-Sn-Pg'	Cm-Sn-Ls	UIE-Stm _s mm	Stm _s -Stm _i mm
Pre-treatment	<AR	5.7%	68.7%	0	0
	AR	25.7%	14.3%	42.9%	57.1%
	>AR	68.7%	17.1%	57.1%	42.9%
Post-Treatment	<AR	8.6%	42.9%	0	0
	AR	31.4%	25.7%	51.4%	80%
	>AR	60%	31.4%	48.6%	20%

“improved” group and 19 cases (54.3%) in the “greatly improved” group. The mean reduction in the weighted PAR index score was 22.9 and the mean reduction in weighted PAR index percentage was 87.2%.

Discussion

Orthodontic therapy aims at achieving balance and harmony of facial lines, guaranteeing the stability of teeth after treatment and sustaining both healthy oral tissues and an efficient chewing mechanism.¹



The orthodontic treatment standard as judged by the PAR index in the present study was higher compared to the results reported by Richmond et al.¹¹ (regarding the General Dental Services of England and Wales). They reported the average standard of treatment was a 50% reduction in the PAR index scores, and approximately one-third of the patients showed “no improvement” after appliance therapy. This difference in the results can be attributed to the fact that a great proportion of the orthodontic treatment was carried out by a non-specialist (more than 60%), and 70% of the cases were treated with removable appliances. In the present study, all of the cases were treated with an upper and lower fixed appliance and the treatment was performed by the postgraduate student under supervision.

Also the orthodontic treatment standard as judged by the PAR index in the present study was higher than that of the Norwegian Orthodontists¹² in which only a small percentage of patients showed “no improvement” (5%) and the standard of treatment was a 77.8% reduction in the PAR

index scores. However, the specialists did the orthodontic treatment and 90% of the cases were treated with fixed appliances.

Al Yami and Kuijpers-jagtman¹³ used the PAR index to evaluate the orthodontic treatment outcome in the Orthodontic Department at the University of Nijmegen (Netherlands). In their study, the mean reduction in weighted PAR index percentage was 68.9% in the “improved” group and 42.6% in the “greatly improved” group. The orthodontic treatment standard in their study was less than the present study.

It has been reported the use of upper and lower fixed appliances had the greatest influence on the outcome of treatment. When the treatment with the upper and the lower fixed appliances were compared, it was found the mean percentage reduction in PAR index score was 71% for the UK and 78% for Norwegians.^{11,12,14} Undoubtedly, removable appliances are less effective than two arch fixed appliances treatment.

Skeletal Cephalometric Changes

There are improvements in the skeletal anterior-posterior measurements which occurred in 51.4% of the cases in regard to ANB, 40% for SNA, and 20% for SNB with a significant difference between improved and worsened ($P < 0.0001$ for SNB). (Table 4)

According to the post-treatment measurements, most of the cases were all still outside the AR below for SNA as well as SNB angle and above the AR for ANB angle. (Table 1) The limited improvement in the skeletal anterior-posterior measurements may be due to the fact major skeletal discrepancies rarely improved with orthodontic treatment alone.^{15,16} The results of the present study match the work of Holdaway¹⁷, where he

Table 4. Changes in percentage of cephalometric skeletal variables from pre to post-treatment (improved/worsened).

Skeletal Variable	SNA	SNB	ANB	PP/SN	MP/SN	PP/MP
Improved	40%	20%	51.4%	34.3%	14.3%	17.1%
Worsened	60%	80%	48.6%	65.7%	85.7%	82.9%
Level of Sig. (P)	NS	****	NS	*	****	****

$P < 0.05$ *, $P < 0.0001$ ****, NS= Not Significant

found the changes in the apical bases during treatment greatly depend on the growth. The reduction of ANB is mainly due to the changes at SNA. The causes for these changes are the inhibition of maxillary alveolar growth and the retraction of upper incisors.

Tahir et al.³ observed there was marked improvement in the ANB with orthodontic treatment. The orthodontist may concentrate more in correcting the ANB angle because they usually correct the overjet. The large percentage of cases for SNB in the worsened group could be related to the vertical changes in the mandible. As the mandibular plane angle increases, the SNB angle decreases.^{18,19}

There were more cases in the worsened groups in all three vertical measurements: PP/SN (65.7%), MP/SN (85.7%), and PP/MP (82.9%) with a significant difference between improved and worsened in all three parameters (P = 0.050, P < 0.0001, and P < 0.0001, respectively.) (Table 4)



MP/SN and PP/MP, in most of the cases, started above the (AR) and remained above or even became worse (Table 1). This may be due to the increase in the mandibular plane angle and the extrusion of the posterior teeth as a result of poor

vertical control and the use of extrusive mechanics, e.g., cervical headgear, intermaxillary elastics.^{16,18,19,20,21,22}

Few orthodontists believe the mandibular plane angle is relatively stable during growth and treatment. Bjork²³ demonstrated the modeling changes along the lower border of the mandible tend to mask mandibular rotation during growth. Tahir et al.³ reported there was no significant change in the mandibular plane angle.

Even with the large number of studies done in this area, there was still a debate if opening rotation of the mandible during treatment is maintained, closed, or continues to open after treatment.^{16,19,21,24,25,26}

Even though the skeletal variable “ANB” was statistically improved compared to the AR before treatment, the result of the post-treatment skeletal variables of the present study indicated the orthodontists did not reach the AR for any of the evaluated skeletal variables. Therefore, one can state, the majority of the treated patients did not even reach the mean values of those skeletal variables (Table 1).

Dental Cephalometric Analysis

The interincisal angle (UIA-UIE/LIE-LIA) in 65.7% of the cases was improved with marginal significant difference between improved and worsened (P = 0.0502) (Table 5). In post-treatment, most of the cases were outside the AR. In fact, 71.4% were below, 22.9 % were above, and only 5.7% were in the AR. (Table 2) The improvement of the interincisal angle (UIA-UIE/LIE-LIA) is very important for the stability of the overbite and prevention of anterior teeth extrusion as reported by Steiner.²⁷

Table 5. Changes in percentage of cephalometric dental variables from pre to post-treatment (improved/worsened).

Dental Variable	UIA-UIE/ LIE-LIA	UIE-UIA/ PP	LIE-LIA/ MP	UMT ⊥ PP MM	UIE ⊥ PP MM	LMT ⊥ MP MM	LIE ⊥ MP MM
Improved	65.7%	57.1%	40%	37.1%	28.6%	42.9%	42.9%
Worsened	34.3%	42.9%	60%	62.9%	71.4%	57.1%	57.1%
Level of Sig. (P)	*	NS	NS	NS	**	NS	NS

P < 0.05 *, P < 0.01 **, NS = Not Significant

The results showed the inclination of maxillary incisors to palatal plane (UIE-UIA/PP) was improved in 57.1% of the cases. In post-treatment, most of the cases were outside the AR, 42.9% were above, 40% were below, and only 17.1% were in the AR. On the other hand, the inclination of mandibular incisors to mandibular plane (LIE-LIA/MP) was improved in 40% of the cases, whereas in post-treatment most of the cases were outside the AR, 51.4% above, 28.6% below, and only 20% were in the AR.

The large numbers of cases were in the worsened group for LIA-LIE/MP and most of them were above the AR (i.e., proclined lower incisors). This could be due to the use of class II elastics during treatment or resolving lower arch crowding with non-extraction treatment. According to Tweed²⁸, the lower incisors should be uprighted over their basal bone and not proclined. Houston et al.²⁹ advocated maintaining the labiolingual position of the lower incisor to enhance stability (Table 2).

Similar results were reported by Tahir et al.³ in which the interincisal angle and the inclination of maxillary incisors to the palatal plane showed marked improvement, whereas the inclination of mandibular incisors to the mandibular plane were proclined.

There were more cases in the worsened groups in all the dental vertical measurements: UMT_⊥PP (62.9%), UIE_⊥PP (71.4%), LMT_⊥MP (57.1%), and LIE-MP (57.1%) with UMT_⊥PP significantly worsened (P = 0.0050). (Table 5) All of the vertical dental measurements were above the AR after treatment (i.e., extruded), and this can be explained by the use of extrusive mechanics, e.g., cervical headgear, intermaxillary elastics.^{16,18,19,21,23} The data showed all vertical dental measurements were higher or above the AR. This is more

related to dental extrusion (rather than intrusion) as an undesirable effect of the use of extrusive mechanics such as cervical headgear, intermaxillary elastics, and nitinole arch wires in our treatment. Similar results were obtained by Maxwell and Jack^{24,25} where extrusion occurred in the lower molars and incisors and to a lesser degree of the upper molars and incisors.

In the present study, even though the improvement of the dental alignment and occlusion was established as judged by the dental model evaluation, cephaometrically some dental parameters were improved while others were worsened by the treatment in relation to skeletal or soft tissue bases. This may indicate the need for careful diagnosis and treatment planning taking into consideration not only the dental alignment and occlusion but also the dental relationship to other skeletofacial structures.

Soft Tissue Cephalometric Changes

There were more cases in the improved groups in all soft tissue measurements: G-Sn-Pg' (65.7%), Cm-Sn-Ls (65.7%), UIE-Stm_s (60%), and Stm_s - Stm_i (85.7%), with significant differences between improved and worsened groups for the angle of facial convexity (G-Sn-Pg'), the nasiolabial angle (Cm-Sn-Ls), and the interlabial gap (Stm_s - Stm_i). (Table 6)

Most of the cases had an angle of facial convexity (G-Sn-Pg') which was above the AR before treatment and even after treatment but to a lesser degree (from 68.7% to 60%). This is similar to the finding observed for the ANB angle and proves the changes in the soft tissue profile correlated well with the changes in the skeletal profile.^{30,31,32} Even with the amount of improvement in the nasolabial angle (Cm-Sn-Ls), most of the cases were still below the AR after treatment (42.9%) (Table 3).

Table 6. Changes in percentage of cephalometric soft tissue variables from pre to post-treatment (improved/worsened).

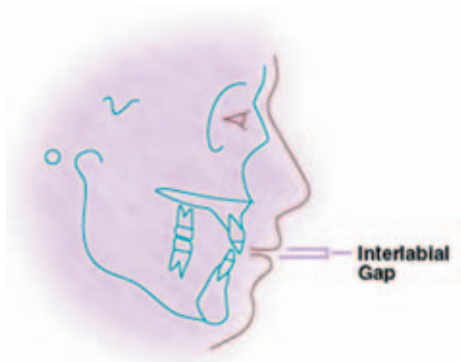
Soft tissue variables	G-Sn-Pg'	Cm-Sn-Ls	UIE-Stm _s mm	Stm _s - Stm _i mm
Improved	65.7%	65.7%	60%	85.7%
Worsened	34.3%	34.3%	40%	14.3%
Level of Sig. (P)	*	*	NS	****

P<0.05 *, P< 0.0001 ****, NS= Not Significant

The improvement in the nasolabial angle could be due to the maxillary incisor retraction and not growth because several studies reported no significant change of nasolabial angle occurred with the growth.^{30,32} Lo and Hunter³² noted the nasolabial angle increases with the increase in the mandibular plane angle and lower facial height. Bloom³⁰, Lo and Hunter³, Bravo³³, Bravo et al.³⁴ found no significant difference in the soft tissue profile and the nasolabial angle between the extraction and the non-extraction treatment. However, they noticed a more retruded lower lip and a more pronounced lower labial sulcus in extraction cases.

The improvement in the upper incisor exposure (UIE- Stm_s) was high. However, 48.6% of the cases after treatment were still above the AR. This could be as the result of the short upper lip or extrusion of the upper incisors. The interlabial gap was markedly improved with treatment. Eighty percent of the cases were in the AR after treatment, with only 20% above the AR (i.e., incompetent lips). Tahir et al. (1997) showed similar results where the interlabial gap was improved with a little change in the nasolabial angle.

Further, similar findings were observed for post-treatment dental and soft tissue variables. (Table 2 & Table 3) However, soft tissue and the interlabial gap variable in the majority of the cases (80%) was found to be within the AR and significantly improved compared to the AR before treatment



(Table 3). This improvement in esthetics could be due to the maxillary and mandibular retraction in cases with incompetent lips. This was considered as one of the major objectives of orthodontic treatment.^{35,5}

The justification for not reaching the mean values or norms could be for the following reasons:

1. Treating all patients to mean values for all cephalometric variables implies that orthodontists are treating all patients to one single profile. This is not possible since the skeletal-dental and soft tissue relationships differ from one patient to another.
2. The effect of orthodontic treatment is mainly on the dentoalveolar structures. Therefore, if there is moderate or major skeletal malrelationship, then orthognathic surgery may be the only way to reach the mean values for some of the variables but not all.⁵
3. Compromising orthodontic treatment in order to camouflage the skeletodental discrepancies implies orthodontists will not aim at treating to the mean values in regard to the skeletal, dental, or soft tissue parameters. The objective at that point is to achieve an acceptable camouflage and stable treatment outcome.^{5,36,37}

Conclusion

It may be concluded from this data that the:

- Skeletal, dental, and soft tissue cephalometric variables are reproducible and reliable.
- Evaluated post-treatment skeletal, dental, and soft tissue cephalometric variables indicate orthodontists did not reach the mean values. However, sagittal maxillomandibular relationship (ANB) and interlabial gap (Stm_s - Stm_i) are the main areas of improvements.
- Orthodontists tend to camouflage the skeletal and dental relationships to improve esthetic and soft tissue relationship.

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