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The Multiharmony Concept For The Cephalometric Evaluation Of Craniofacial Patterns

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□ ABSTRACT □

All the analysis of craniofacialpatterns is essential since a considerable amountof dental compensation can mask the severity of a malocclusion. Disagreement prevails over the standards that should be used to judge the individual values.In this study, a method is presented—the multiharmony method [**MHM**], which assists in treatment planning.The approach was applied to a data set of 75 Syrian adults [35 males and 40 females, mean age 23 years] that had not received orthodontic treatment. They were selected frompatients enrolled at Tishreen University Dental colleage, Lattakia, Syria. The subjects had an ideal or near-ideal occlusion [Class I molar relationship, not more than 4 mm overbite and overjet, and no missing teeth] and a well-balanced face.With multiple regression analysis, the expected value that each angle should take in a norm individual when the remaining angles are given is estimated. The residual difference between the measured angle and its expected value then indicates the deviation from a harmonic appearance in the respective angle. The **MHM** can serves as a supportive tool for the orthodontic expert in the diagnosiss and decision for potential treatment

The key words : Craniofacial Patterns, Cephalometric radiographic , Multiharmony

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التقييم السيفالومتري لأنماط المركب القحفي الوجهي باستخدام مشعر الانسجام المتعدد

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علي علي**

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□ ملخّص □

إن التحاليل السيفالومترية لنماذج المركب القحفي الوجهي مهمة بسبب أن هناك نسبة كبيرة من الحالات المترافقة مع معاوضة سنية تخفي شدة سوء الإطباق الموجود. وهناك جدل واسع حول القيم االمتوسطة التي يجب استخدامها لمقارنتها مع كل حالة فردية .في هذه الدراسة تم استخدام طريقة الانسجام المتعدد الذي يساعد في التخطيط للعلاج. تم الاستعانة بأرشيف ل 75سوري بالغ [35 ذكر 40 أنثى] ومتوسط أعمار 23 سنة لم يتلقوا أي علاج تقويمي سابق من أرشيف المرضى المراجعين لقسم تقويم الأسنان والفكين في جامعة تشرين في سورية . أفراد العينة لديهم علاقات رحوية صنف أول حسب أنجل والازدحام أقل من 4 مم وبروز وتغطية طبيعيين ووجه متوازن لا يوجد تشوهات .

باستخدام معامل الانحدار المتعدد تم التوصل لمعادلات تعطينا القيمة المتنبأة لكل متغير ومن ثم تتم مقارنتها مع القيمة الموجودة لدى المريض ، إن الفرق بين الزاويتين [القيمة المتنبأة والقيمة الموجودة] يسمى باقي وهذا الباقي يشير إلى مدى الانحراف عن القيم المنسجمة حسب كل متغير . الانسجام المتعدد بإمكانه أن يكون أداة داعمة في التشخيص لطبيب التقويم وفي التخطيط للعلاج .

الكلمات المفتاحية : المركب القحفي الوجهي ، الصور السيفالومترية الجانبية ، الانسجام المتعدد

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Introduction:

Conventional cephalometric diagnosis is clinically based on the use of population mean and range for separated craniofacial measurements**[1,2,3]**.Basically, mean values with standard deviations [SDs] are used in the cephalometric analysis to describe a norm population**[4], [5]**.*Solow* stated that a major drawback of these conventional cephalometric analysis was the use of isolated craniofacial parameters, without their possible interdependence taken into account**[6]**. However, significant, correlations among cephalometric skeletal variables [topographical correlations]had been assessed [Solow, 1966] [**7**]. This finding led to the concept of craniofacial pattern, which can be described by correlated sagittal and vertical skeletal parameters This implies that even though all the cephalometric values of a patient lie beyond one standard deviation from the population mean, they may still be considered acceptable if they maintain certain relationships with each other [**8**]. It appeared advantageous therefore to substitute the norm intended as a population mean with a new norm constructed on the variability of the associations among suitable cephalometric variables[**9**].A comprehensive analysis for the assessment of individual craniofacial patterns was performed bySegnerand bySegnerandHasund, who constructed floating norms for the description of sagittal and vertical skeletal relationships in a sample ofEuropean adults**[10].** Thus, the term floating normswas used to describe individual norms that float, in accordance with the variation in correlated cephalometric measurements**[11]**The five basic cephalometric measurements [SNA, NL-NSL, NSBa , ML-NSL, SNB] that were found to show evidence of correlations with each other**Figure(1)**. It should be noted that the sellanasion line was shared by all measurements, thus enhancing the power of mathematical correlation among the five variables.

In order to decide about the diagnosis and the form that treatment should take into account, it is important to identify the causes, i.e. the directions in multidimensional space, in which an individual deviates from the norm cloud. This requires three steps:

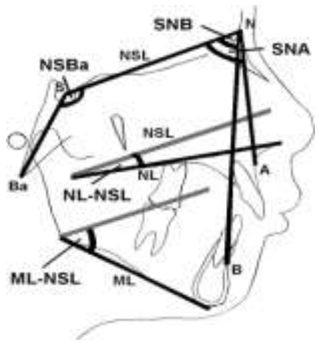
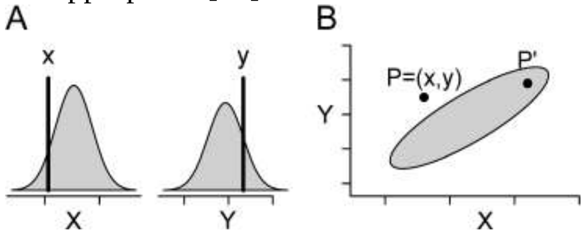


Figure (1)The five basic cephalometric measurements [SNA, NL-NSL, NSBa , ML-NSL, SNB]

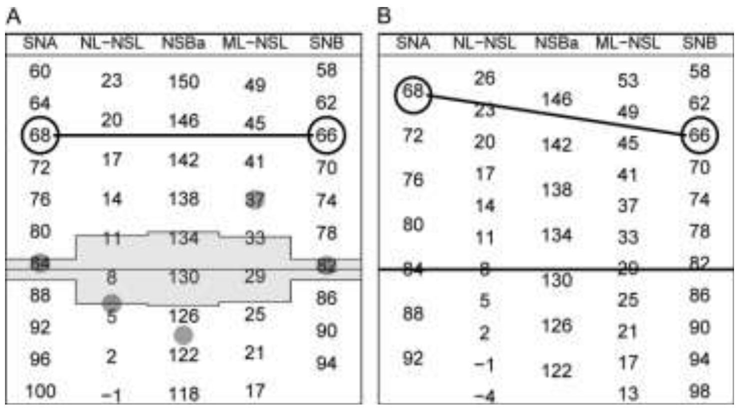
first, a description of the location of the norm cloud, of the scale andinterdependencies between the *k* variables; second, deviations from the norm cloud should be identified in terms of the original angles, such that possible causes of misalignment can be identified, and finally, possible treatment should be suggested, for example, by visualizing the effects that this treatment has on the relationship between the angles**[12].**Thus, the term "floating norms" is used to describe the individual norms that vary [float[in accordance with the variations of correlated cephalometric measurements.

This idea can be useful, but it disregards certain multidimensional relations **Figure**(**2**), so that the diagnosis may not be appropriate**.[13]**



Figure(2)Illustration of the idea that the concept of harmony requires the consideration of relationships between variables. Let X and Y be two cephalometric angles. If these are positively correlated in the population [cloud of points illustrated in B], an individual with measurements P = [x,y] may appear normal in the univariate representation [univariate distributions illustrated in A] although the relationship between the angles x and y differs from the normal relationship [B], which can thus not be considered harmonic. Vice versa, an individual with extreme measurements [P′ = [x′,y′] in the univariate representations may still be harmonic if the correlation between its measurements agrees with the relationship in the norm cloud

In addition, FN-harmonic angle combinations depend on the chosen independent variable: a harmony box based on SNA differs from the one based on SNB see **Figure(3).**Finally, the vertical position of the harmony scheme crucially determines which angles had to be considered abnormal in one particular individual**.[14]**



Figure(3)The harmony box as proposed by Segner[1989] derived from the Korean norm population analysed in the present study. [A] For each SNA value, each other angle is predicted with simple linear regression from SNA. Values on a horizontal line were identified as ‘harmonic’. The grey area [harmony scheme] represents deviations of ±1 standard errors derived from multiple linear regression. The five angles of an individual were represented as grey points. B: Harmony box derived from the same data set, with SNB as the predictor

The ‘multiharmony’ method [MHM] was introduced in detail by *Bingmer*[2008] [**15**].The MHM defines a set of angles as multiharmonic if every angle corresponds to its prediction derived from all other angles with multiple linearregression. The difference between the predicted and the observed value in angle i then indicates potential abnormalities in this angle**[16],[17**]

Aims and importance of the research:The aim of this studyis to develop a method that avoids the problem of predictor choice and that regards the interdependencies of skeletal structures when investigating the agreement between multiple cephalometric angles .

Materials and methods*:*

A sample of 75 untreated adults [35 males,40 females] was selected from the files of the department of Orthodontics of Tishreen University at Lattakia , Syria . All the patients presented full permanent dentition [mean age 23 years]. The subjects had an ideal or near-ideal occlusion [Class I molar relationship, not more than 4 mm overbite and overjet, and no missing teeth] and a well-balanced face**[18],[19]**,[**20],[21]**An approach is presented that is related to the harmony box [*Hasund* and *Segner*, 2002 [**22**]We will construct a harmony box that based on correlated cephalometric variables, which may serve as a valuable diagnostic tool in orthodontic treatment planning [**23**] by analyzing the harmonious relationships of existing individual craniofacial patterns among Syrians, after that as asecond step, avoid the problem of predictor choice by taking into account the multidimensionalrelationship between all variables **Figure**(**4**). The following measurements were carried out using an orthodontic diagnostic software program [Radiant Dicomeviwer]: SNA, SNB, NL–NSL, ML–NSL, and NSBa**Figure(1)** .All cephalometric radiographof the sample were taken with the same device [Cranex 3+Ceph; Soredex, Schutterwald, Germany].

Statistical Analysis:

The statistical examination of the recorded data comprised:

1] calculation of Pearson's correlation coefficients;

2] linear regression analysis;

3] multiple regression analysis.

All data analyses were performed with the use of the Statistical Package for the Social Sciences [SPSS] program for Windows, version 11.5 [SPSS Inc, Chicago, Ill].

Results and Discussion:

Results:

In order to describe the multivariate relationship between the angles in the norm population, multiple linear regression was used: Let $Xi = [x1i, ..., xni]$ denote the observations of all *n* norm individuals in angle *i*. Then the 'harmonic' value $\hat{}iX$of angle i was estimated from all other angles $X1,..., Xi–1, Xi+1,..., Xk$with multiple regression

$\hat{}iX$ =bi,0+bi,1 X1……+bi,i-1 Xi+1 +……+bi,kXk ,

i = 1,…..k , the coefficients *bi,0,...,bi,k*, *i* = 1,..., *k*, which describe the multivariate relationship, that are perceived as normal were estimated from the norm population The residual for the variable X is r = $X\ i - \hat{}iX$

i.e. the difference between the predicted and the observed size of the angle, indicates potential abnormalities in angle *i*.

In the second step, the system of equation [1] is used as a reference for additional individuals *Y* with measured angles [*y*1,..., *yk*] as follows: for each angle *i*, the value $\hat{}iy$that would be expected in a norm individual with values *y*1, *y*2,..., *yi*–1, *yi*+1, ..., *yk*. is predicted by [1]:$\hat{}iY$ =bi,0+bi,1 Y1……+bi,i-1 Yi+1 +……+bi,kYk

The residual for the variable Y is r = $Y\ i - \hat{}iY$

In this representation, each column shows one angle [SNA, NL–NSL,. .]. The ordinate of a point represents the size of the residual in that specific angle: if it is located close to zero, this indicates a small residual, i.e. the observed angle NL–NSL agrees closely with the value that is predicted from the other angles [SNA, NSBa, ML–NSL, and SNB]. A large residual indicates potential abnormalities in angle. Theseare the equations for every angle :

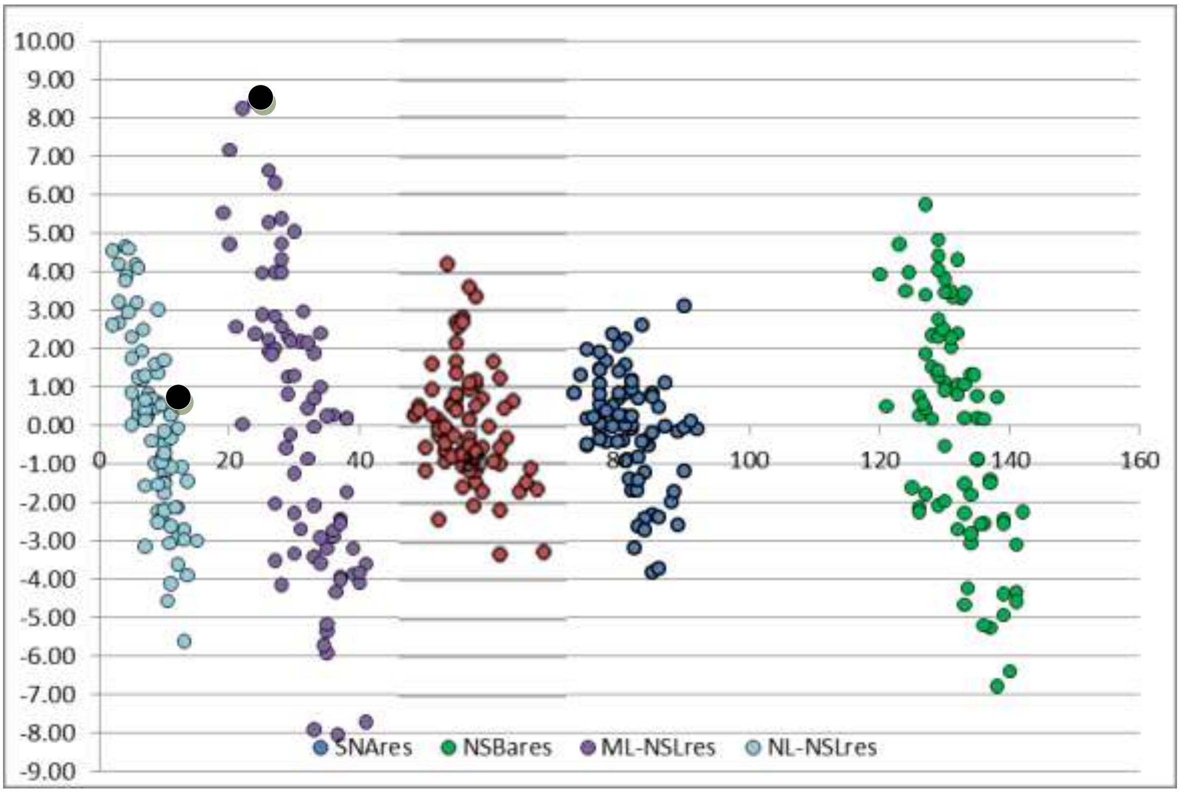
SNApredection = 0.81* SNB - 0.045*NSBa - 0.070*ML-NSL -0.031*NL-NSL+ 26

SNBpredection=0.81*SNA-0.13*NSBa -0.057*ML-NSL + 0.011*NL-NSL+ 31.81

NSBapredection=-0.63*SNB -0.20 *SNA -0.20*ML-NSL + 0.41* NL-NSL + 200

ML-NSLpredection=-0.33*NSBa -0.44*SNB -0.54*SNA + 0.24* NL-NSL + 153.27

NL-NSLpredection=0.093*ML-NSL+0.26*NSBa+0.03*SNB-50.095*SNA - 24.675



Figure(4)the difference between the predicted and the observed size of each angle, indicates potential abnormalities at them

Discussion:

In the present research, a graphical method was developed that provides three tools that may be helpful in the diagnosis of orthodontic patients and in the choice and evaluation of potential treatment [Bingmer, 2008]. Firstly, it is necessary to quantify and describe ‘norm’ faces, i.e. the location, range, and correlation between the angles that are usually perceived as harmonic. Secondly, one should be able to identify deviations from these norm relationships in terms of the original angles, and finally, the method should be able to suggest a potentially successful treatment and to visualize its effects.In order to answer these questions, the concept of **MH** was introduced: a combination of angles of the face was considered [perfectly]multiharmonic if every individual angle corresponded to its prediction derived from all other angles with multiple regression**Figure(5)**

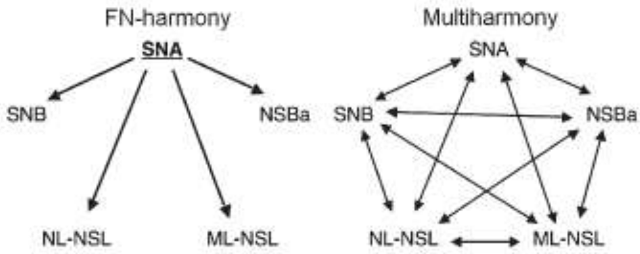


Figure (5)Relationships taken into account by the floating norms (FN) harmony box (left) and by the multiharmony method (MHM; right): FN relates all variables to one pre-identified predictor (here: SNA), while MHM is symmetric in the sense that it relates every variable to all other angles.

First,The regression coefficients that quantify multiharmonic relationships were extracted from a predefined norm population. In asecondstep, a patient's angle combination was investigated by transforming the measurements of the angles into the residuals between the predicted and observed angles. These residuals were then represented in a residual plot. By comparing the residuals of a patient with the cloud of residuals obtained in the norm population, deviations from MH in individual angles can be identified. This can be helpful in the evaluation of a patient's original status, of potential treatment effects, and of the true treatment results.

Applying this procedure to all *k* angles yields *k* residuals, which can be visualized in a 'residual plot' **Figure(4)** , a specific type of parallel co-ordinate plot [Inselberg and Dimsdale, 1990].In this representation, each column shows one angle [SNA, NL–NSL, . . .]. The ordinate of a point represents the size of the residual in that specific angle: if it is located close to zero [e.g. the black point in column NL–NSLin **Figure(4)**, this indicates a small residual, i.e. the observed angle NL–NSL agrees closely with the value that is predicted from the other angles [SNA, NSBa, ML–NSL, and SNB]. A large residual [e.g. the black point in column ML–NSL in **Figure (4)** indicates potential abnormalities in angle ML–NSL.The residual plot can be used to evaluate the resulting angle combination and to track its development during follow-up. The resulting new angle combination can be visualized in the residual plot [see Case Report]. The main change that was observed was a considerable reduction in SNB, and the residual plot indicates that this treatment improved the agreement between the angles: all residuals could be shifted into the norm cloud. In addition, one can see that slight changes have occurred. A slight increase in SNB indicates a potentially critical development, pushing the point to the border of the norm cloud.This indicates that the MHM residual plot can help to map the actual condition of a patient and support the search for successful treatment. In addition, it can be used to evaluate treatment and to trace an individual in the follow-up period. This could be useful in the timely detection of potentially critical developments.

Multiharmony and FN-harmony

As noted, the MHM residual plot and the FN-harmony box presented by Segner[1989] can lead to comparable interpretations of a patient's profile. In general, both approaches are based on linear regression and are thus highly related, particularly near the centre of the norm cloud. Because all regression hyperplanes cross this centre, an observation in the very centre of the norm cloud is perfectly harmonious with both methods **Figure (5)** .

However, there is a conceptual difference between the methods. First, the MHM does not identify one specific predictor but compares every angle with all other angles . As a consequence, the definition of multiharmony is consistent and context-free. In contrast, the harmony box requires one angle to be chosen as a predictor and thus the resulting definition of the FN-harmony depends on that predictor. A set of angles that is FN-harmonic when based on SNA will not be perfectly FN-harmonic when based on SNB**Figure (3).**

Identifying treatment progress with the MHM**[Case Report]**

Experiencein practical orthodontics is one of the most important factors in the prediction of the outcome of treatment. However, the MHM can be a helpful tool in the assessment of a patient's problems and the choice of a suitable treatment.In the first place, the residual plot can indicate the angles within a patient's profile that show deviations from MH.

A patient's initial values**Figure (6**) are shown in **Table (1)**. In order to map the initial condition, one can represent the patient in the residual plot **Table (2**). Here, this representation indicates that SNB is too small, whereas SNA and ML–NSL are more normal. For orientation, the representation in the residual plot**Figure (7**).In order to investigate different treatment effects, the resultsof changes in individual angles with the help of the residual plot **Figure(8**) can be visualized. For example, one could try to change one of the deviating angles, i.e. SNB [A].**Figure (8**) indicates that a reduction in SNB by approximately 3 degrees would result in a multiharmonious angle combination .

Figure (6) Class II deviation1 for a patient , his mandible is located so distally

Table (1) Patient's initial values

SNA	SNB	NSBa	ML-NSL	NL-NSL
81.7	72	137	33.6	11.2

Table (2) Patients residual plot after we calculated every predicted angle ,then we substructed every angle from its prediction value

SNA	SNB	NSBa	ML-NSL	NL-NSL
-5.9	5.8	-0.36	-0..67	-1.35

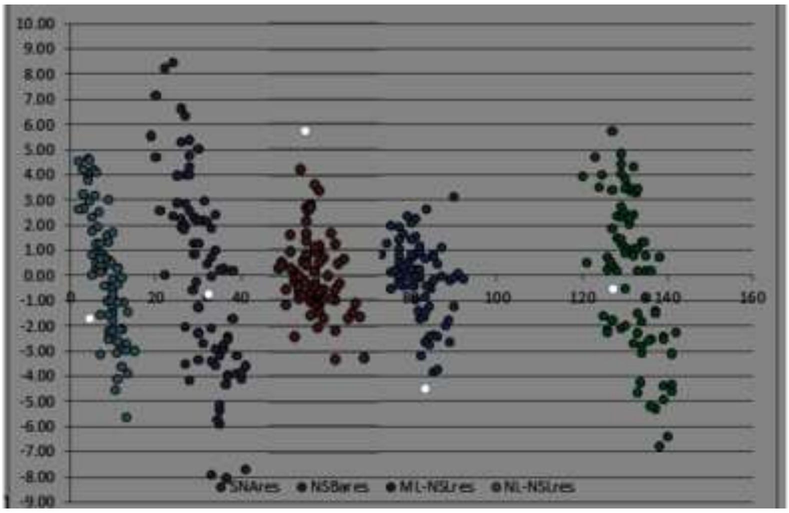


Figure (7) The patient risdual plot,the white points indicate for every residual angle , need should be done to correct them

we note that SNA,SNB are located outside the cloud of harmony and the treatment we Then we applied our equations for every angle to determine the predection value , here we advanced the SNB, 3 degree . the **Figure [8]** represents the residual plot after we advanced the SNB , and the **Figure [9]** represents the patients cephalometric after treatment and the **Table [3]** represents the value after treatment .

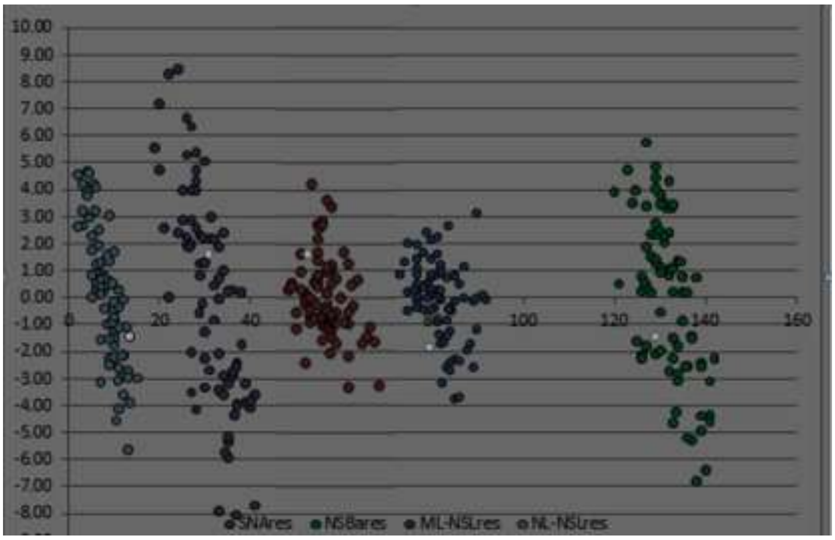


Figure [8] We note that advancing the mandible 3 degree put the SNA,SNB inside the cloud of harmony

Figure (9)The patients cephalometric after treatmen

Table (3)The value after treatment

SNA	SNB	NSBa	ML-NSL	NL-NSL
80	75	137	31	11.2

Conclusions:

1. The MHM is the identification of specific variables that show deviations from relationships which would be perceived as normal. In addition, the MHM helps to graphically compare various potential treatments and investigate whether they lead to a multiharmonic angle combination

2. the MHM residual plot and the FN-harmony box presented by Segner[1989] can lead to comparable interpretations of a patient's profile. In general, both approaches are based on linear regression and are thus highly related, particularly near the centre of the norm cloud. However, there is a conceptual difference between the methods. First, the MHM does not identify one specific predictor but compares every angle with all other angles As a consequence, the definition of multiharmony is consistent and context-free , the harmony box requires one angle to be chosen as a predictor and thus the resulting definition of the FN-harmony depends on that predictor.

3. The MHM can thus serve as a supportive tool for the orthodonticexpert in the diagnosis and decision for potential treatment.

4. Finally, it can be a useful tool in follow-up studies for the identification of critical developments.

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