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# Determination of the occlusal plane in completely edentulous patient by computerized cephalometric method (A comparative study). Part II

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## ABSTRACT

**Aim**: to investigate the level of ala–tragus line of dentulous nearest to be parallel to the three levels of occlusal plane orientation in the complete denture construction, by evaluation of cephalometric measurements. Designing new special direct and indirect computer digitalization program, to analyze the cephalometric radiographs, or their tracing in the best treatment for edentulous patient. **Materials and Methods**: Twenty dentate participants in addition to the same group of part I (20 edentulous participants) fulfill specific criteria to investigate the validity of using the ala–tragus line as visible soft tissue guidance in orienting the occlusal plane. Eighty lateral cephalometric radiographs were done (one for each dentate, and three radiographs; one for each set of complete dentures). Special computerized program named CoDiC, which was developed in Matlab and Photoshop programs to analyze digital the colour density of the hard and soft tissue with tracing. **Results**: showed the occlusal plane of dentulous participants was parallel to ala–tragus line located between the middle and inferior point of the tragus of the ear. This result was coincide with results of occlusal plane orientation of edentulous patient. Computerized digitalization program "CoDiC" was designed and applied for cephalometric tracing and analysis to improve treatment of edentulous participants. **Conclusions**: There is a strong relationship between the occlusal plane and other craniofacial measurements especially those determinei-ng skeletal jaw relationshipand those determining facial types.

**Key words**: Computerized cephalometric, Occlusal plane, Edentulous patient.

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## INTRODUCTION

Many cephalometric investigations have been undertaken to study the occlusal plane in relation to prosthodontic craniofacial landmarks and to compare the position of the occlusal plane in natural and artificial dentition.(1)

The occlusal plane was defined as that line bisecting the overlapping cusps of the first molar and the incisor overbite.(2) While other authors indicated that the location of the occlusal plane differ according to facial types.(3,4) There was a close correlation of the occlusal plane to the maxillary plane in both dentulous and edentulous patients.(5)

It was found that the occlusal plane is steeper in dolichocephalic face and rather horizontal in brachycephalic face.(6,7) Also they found a strong correlation of the geometric center of the ramus of the mandible with the posterior inclination of the occlusal plane, and the incisal inclination in relation to skeletal and soft tissue landmarks.(8)

Bassi *et al.*,(9) evaluated cephalometrically a group of edentulous patients, whose complete dentures, subjectively and objectively correct, had been constructed according to clinical parameters. The vertical dimension of occlusion, the orientation of the occlusal plane and the subdivision of the denture space were examined.

In a cephalometric study of dentate subjects, the line extending from the lower border of the ala of the nose to the lower border of the external auditory meatus can be used safely to orient the artificial occlusal plane parallel to it as it represents a fixed reference line.(10)

There is an increasing trend to use computers to assist in cephalometric analysis.(11) The increasing power and decreasing cost of small computer system suggest to enter cephalometric data in a computer–compatible format.(12) Computerized cephalometric analysis can include both landmark identification and determination of linear or angular measurements.(13)

Some investigators(14,15) showed insignificant differences between computerized and manual methods. Chen *et al*.,(16) reported differences in the accuracy of landmark identification even between different computerized digitization methods.

The purposes of this research were to investigate the level of ala–tragus line of dentulous nearest to be parallel to the three levels of occlusal plane orientation in the complete denture construction, by evaluation of cephalometric measuring of the radiographs. Design special direct and indirect computer digitalization program to aid dentist to analyze the cephalometric radiographs or their tracing in the best treatment for edentulous patient.

## MATERIALS AND METHODS

Twenty dentate participants (group I) in addition to the same group of part I (20 edentulous participants, group II). Each participant was seated on a dental chair. Information, extra and intraoral examinations were done to check their fulfillment of the criteria for each group required in sample selection. An important thing was that each participant should accept exposure to x–radiation for the research purpose.

*Group I*: A group of dentate participants (20) young adults with age range of 22–32 years, presence of 28 to 32 permanent teeth with pleasing profile, bilateral Class I (normal occlusion), with overbite and overjet ranging from 2–4 mm.

No apparent facial asymmetry, history of facial trauma, clinical temporomandibular joint pathosis, history of orthodontic, orthopedic treatment or maxillofacial surgery or extensive dentistry, history of oral habits and no history of mouth breathing.

Four triangular pieces of radiopaque material (lead foil, thick gauge No. 6) were attached to the skin of the left side of the participant's face. Keeping the apices of these triangles pointing toward inferior border of the ala of the nose, and the other three markers were on the superior, middle (tip) and inferior point of the tragus of the ear.

For edentulous patients (group II), additional radiopaque markers were adapted to the mesio–incisal angle of the left maxillary central incisor, and on the mesio–palatal cusp tip of the left maxillary first molar to demonstrate the artificial occlusal plane level on the radiographs.

One lateral cephalometric radiograph was done for each participant of group I, and three for each participant of group II; one radiograph for each set of complete dentures by using a panoramic–cephalometric x–ray machine type (SOREDEX Orion Corporation, CRANEX 3 plus) with magnification factor of 1.13.(17)

Eighty lateral cephalometric radiographs were traced.(18–20) Sixteen cephalometric landmarks of dentate participants were used for analyzing the cephalogram(18, 19) (Figures 1,2,3). Angles were made and measured to the nearest half degree.(2, 19, 21)

*Measurment of (FH AT) and (OP AT) Angles*: (A). Radiographs of group I (dentate): These measurements were obtained from the angles formed between Frankfort Horizontal Plane (FH) and each of superior ala–tragus ($AT_1$), middle ala–tragus ($AT_2$) and inferior ala–tragus ($AT_3$) lines respectively participants (FH $AT_1$, FH $AT_2$ and FH $AT_3$ angles). While second measurements were obtained from the angles formed between the occlusal plane(OP) and each of superior ($AT_1$), middle ($AT_2$) and inferior ($AT_3$) ala–tragus lines respectively (OP $AT_1$, OP $AT_2$ and OP $AT_3$). (Figure 2) (B). Radiographs of group II (edentulous) participants. One ala–tragus line was drawn for each one of the three radiographs of each edentulous patient. This ala–tragus line was chosen according to the number that was fixed on the radiograph (Figure 3).

*Designing Computerized Cephalometric*

*Measuring technique*: A special computerized program was designed for automatic cephalometric radiographs analysis and named "CoDiC" which was developed in Matlab and Photoshop programs and stored in compact disk.

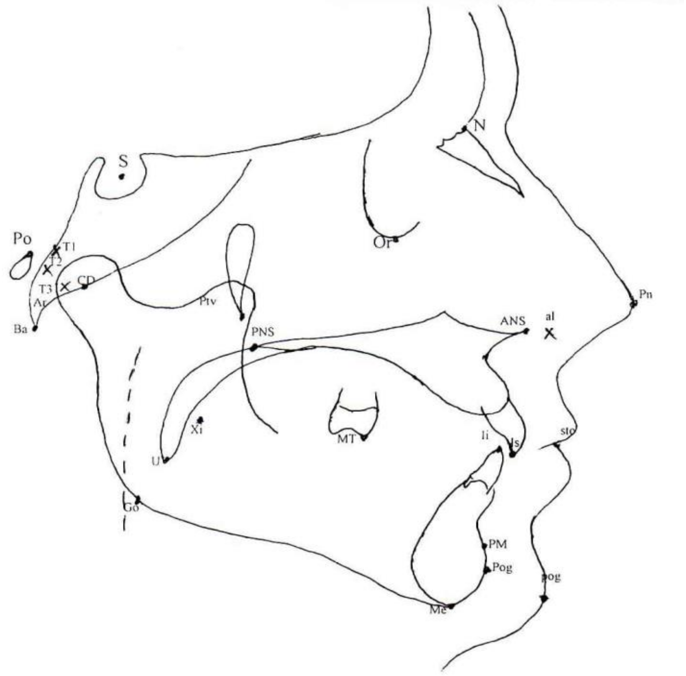


Figure (1): Cephalometric landmarks of dentate participants; N: Nasion; S: Sella; Po: Porion; Or: Orbitale; ANS: Anterior nasal spine; PNS: Posterior nasal spine; A: Subspinale; Is: Incisor superius; MT: Molar cusp tip; PM: Protuberance menti; Pog: Pogonion; Me: Menton; Go: Gonion; Ar: Articulare; CD: Condylion; Xi: Center of ramus.

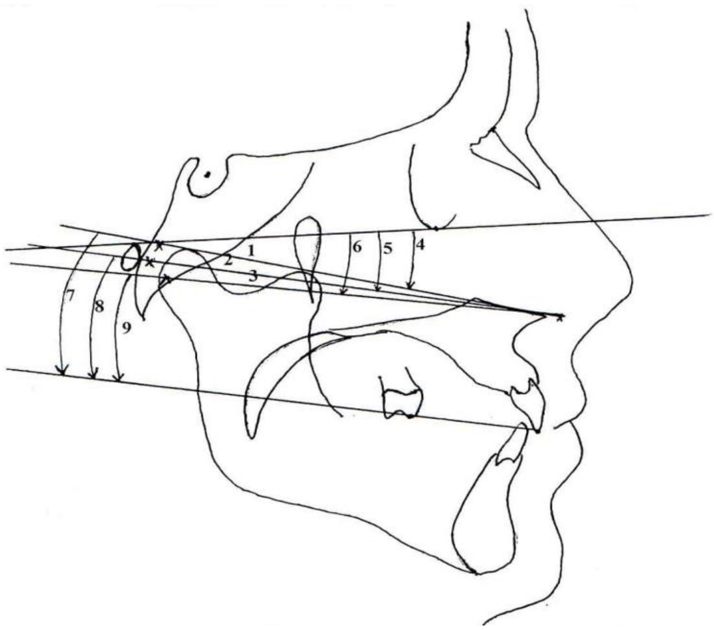


Figure (2): Ala–tragus lines and angles (Clinical case); 1: Superior AT line; 2: Middle AT line; 3: Inferior AT line; 4: ($FH.AT_1$) angle; 5: ($FH.AT_2$) angle; 6: ($FH.AT_3$) angle; 7: ($OP.AT_1$) angle; 8: ($OP.AT_2$) angle; 9: ($OP.AT_3$) angle.

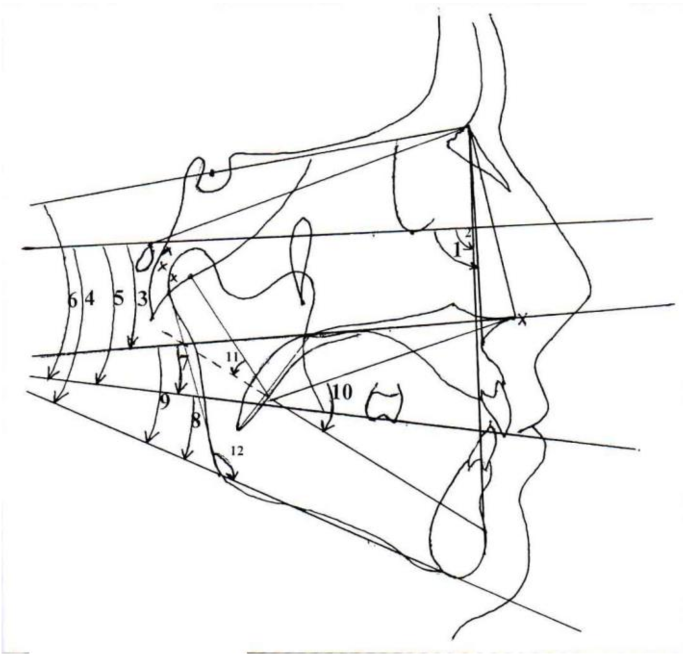


Figure (3): The cephalometric angular measurements. 1; Maxillary depth; 2: Mandibular depth; 3: FH.PP; 4: FH.MP; 5: OP.FH.; 6: OP.NS.; 7: OP.PP; 8: OP.MP; 9: PP.MP; 10: L.F.H; 11: MB; 12: Gon. A

The image of the radiograph was converted to digital data using digital scanner and digital camera to be analyzed by the computer. This digital image of the radiograph is a matrix of square pieces, called pixels that form a pattern from which the original image of the radiograph can be reconstructed for visual display on computer monitor. The matrix of the radiograph varies in its pixel density represented by a continuous grayscale ranging from zero (dark black) to 255 (light white).

The matrix was then adjusted to a standardized size to improve the resolution and clarity of the image and uniformity of the images of all radiographs to be treated and analyzed in the same manner.

After the radiographic image was entered into the computer, “CoDiC” program can analyze the differentiation of the colour density of the hard and soft tissues by grouping the 255 grayscales into several grades. Each grade consists of specific number of grayscales ranging from minimum to maximum values.

The matrix was divided into four sections; each one has its own resolution. An automatic identification and tracing of all the peripheral soft tissues and skeletal outlines and some of the internal structures were successfully done on the image of the cephalometric radiograph.

*Application of CoDiC Program*:

- *Direct method*: **C**ephalometric landmarks were identified directly on the radiographic image. These landmarks include Orbitale (Or), Porion (Po), Incisor Superius (Is), Mesiopalatal cusp of the maxillary first molar (MT), Superior, Middle and Inferior points of the tragus of the ear and the position of the inferior border of the ala of the nose, and drawing of the lines that join these points to measure the angles formed automatically by the computer program CoDiC ($OP.AT_1$, $PO.AT_2$, $OP.AT_3$, $FH.AT_1$, $FH.AT_2$, $FH.AT_3$) (Figure 4).
- *Indirect method*: the conventional traced image of the radiograph on acetate paper was entered into the computer by using digital scanners. The cephal-ometric measuring procedures can be done either by direct identification and pointing of very detailed landmarks on the tracing image or these landmarks were identified on the tracing paper and then captured and measureed by the computer.

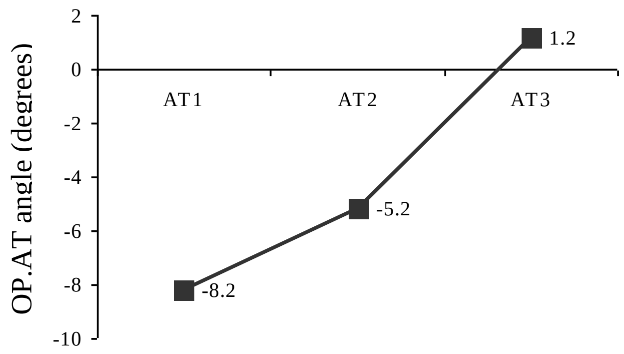


Figure (4): Degree of angulations of the three ala–tragus lines with the natural occlusal plane in total group I

The measurements (intra exam), (inter exam), conventional or the manual method and the cephalometric analysis of the "CoDiC" program were performed using Student's t–test to differentiate significant differences at p at 0.05 level.

All the obtained data in this study were processed using SPSS computerized program to calculate means, standard deviations, standard error of deviations, and Pearson's (r) correlation coefficients.

## RESULTS

Table (1) displaied the results of the intra– and inter–examiner calibrations including angular measurements. The results showed insignificant differences at $p \le 0.05$ between the first and second readings of the same radiographs.

Table (1): Results of inter– and intra– examiner calibrations

| **Variable** | **Intra–Examiner Calibration** | | **Inter–Examiner Calibration** | |
|---|---|---|---|---|
| | **Mean** | ***p*–value** | **Mean** | ***p*–value** |
| **Angular Measurements** | | | | |
| **Maxillary Depth** | 0.4 | 0.333 | 0.444 | 0.357 |
| **Mandibular Depth** | 0.42 | 0.39 | 1.358 | 0.191 |
| **FH–PP** | 0.17 | 0.41 | 1.745 | 0.612 |
| **FH–MP** | 0.10 | 0.47 | 1.615 | 0.295 |
| **PP–MP** | 0.22 | 0.432 | 1.17 | 0.451 |
| **LFH** | 0.311 | 0.41 | 0.17 | 0.54 |
| **MB** | 0.071 | 0.45 | 1.496 | 0.162 |
| **Gon– A** | 0.25 | 0.39 | 0.233 | 0.431 |
| **Op–NS** | 0.27 | 0.4 | 0.711 | 0.411 |
| **Op–FH** | 0.23 | 0.413 | 0.4 | 0.432 |
| **Op–PP** | 0.120 | 0.461 | 1.93 | 0.07 |
| **Op–MP** | 0.021 | 0.49 | 0.01 | 1 |

FH: Frankfort horizontal plane; PP: Platal plane; MP: Mandibular plane; LFH: Lower facial height; MB: Mandibular angle; Gon: Gonion; Op: Occlusal plane; N: Nasion; S: Sella; A: Subspinale

Mean, standard deviations, standard errors of deviations of angular measureements and Pearson's Correlation Coefficient test was done for the measurements formed between the natural occlusal plane and other angular and linear measurements (Tables 2–4).

Table (2): Correlation measurements of occlusal plane and other skeletal landmarks with angular measurements in group I (Dentate participants)

| | OP.FH | OP.NS | OP.PP | OP.MP |
|---|---|---|---|---|
| **Angular Measurements** | | | | |
| **Maxillary Depth** | –0.451* | | | |
| **Mandibular Depth** | –0.465* | | | |
| **FH–PP** | 0.605*** | | | |
| **FH–MP** | 0.598*** | | | 0.614** |
| **PP–MP** | 0.401* | | 0.647*** | 0.754*** |
| **LFH** | 0.480* | | 0.502** | 0.552** |
| **MB** | | | –0.489* | |
| **Gon–A** | | 0.593** | 0.433** | 0.642*** |
| **Op–NS** | | | 0.545** | |
| **Op–FH** | | | 0.503** | |

* Significant correlation at *p*–value ≤ 0.05. ** Significant correlation at *p*–value ≤ 0.01. *** Significant correlation at *p*–value ≤ 0.001. FH: Frankfort horizontal plane; PP: Platal plane; MP: Mandibular plane; Gon: Gonion; Op: Occlusal plane; N: Nasion; S: Sella; A: Subspinale;

Table (3): Descriptive statistics for angular measurements in the total group II (Edentulous participants)

| Variables | Mean | ± SD | ± SE |
|---|---|---|---|
| **Maxillary Depth** | 93.2 | 4.8 | 1.1 |
| **Mandibular Depth** | 91.1 | 4.6 | 1 |
| **FH–PP** | 1.8 | 3.1 | 0.7 |
| **FH–MP** | 21.2 | 3.9 | 0.9 |
| **PP–MP** | 21.2 | 4.2 | 0.9 |
| **LFH** | 42.3 | 3.9 | 0.9 |
| **Gon– A** | 126.2 | 3.6 | 0.8 |
| **Po–N –ANS** | 79.9 | 9.8 | 2.2 |
| **Denture 1** | | | |
| **OP–NS1** | 17.2 | 4.5 | 1 |
| **OP–FH1** | 11.3 | 3.7 | 0.8 |
| **OP–PP1** | 11.8 | 5.4 | 1.2 |
| **OP–MP1** | 5 | 3.3 | 0.7 |
| **Denture 2** | | | |
| **OP–NS2** | 13.2 | 4.4 | 1 |
| **OP–FH2** | 5.4 | 3.7 | 0.8 |
| **OP–PP2** | 6.8 | 5.1 | 1.1 |
| **OP–MP2** | 9 | 3.2 | 0.7 |
| **Denture 3** | | | |
| **OP–NS3** | 4.3 | 4.3 | 1 |
| **OP–FH3** | –0.3 | 4.5 | 1 |
| **OP–PP3** | 3.3 | 2.1 | 0.5 |
| **OP–MP3** | 13.6 | 3.8 | 0.8 |

SD: Standard deviation; SE: Standard erorr; FH: Frankfort horizontal plane; PP: Platal plane; MP: Mandibular plane; LFH: Lower facial hight; Gon: Gonion; Op: Occlusal plane; N: Nasion; S: Sella; A: Subspinale;

Table (4): Descriptive statistics for angular measurements in the total group I with comparison between males and females

| Variables ++ | Total Mean* | ± SD | Sex** | Mean | ± SD | t–test | | 95% CI | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | t–value | *p*–value | LL | UL |
| **Maxillary Depth** | 93.2 | 3.2 | Male<br>Female | 94.5<br>91.9 | 3.5<br>2.5 | 1.930 | 0.070 | –0.2 | 5.4 |
| **Mandibular Depth** | 90.5 | 2.6 | Male<br>Female | 90.7<br>90.3 | 2.9<br>2.5 | 0.333 | 0.743 | –2.1 | 2.9 |
| **FH–PP** | –0.2 | 3.4 | Male<br>Female | –1.2<br>0.8 | 3.8<br>2.7 | –1.358 | 0.191 | –5.1 | 1.1 |
| **FH–MP** | 21.2 | 4.6 | Male<br>Female | 19.7<br>22.6 | 5.2<br>3.6 | –1.457 | 0.162 | –7.1 | 1.3 |
| **Pp–MP** | 21.7 | 5.7 | Male<br>Female | 21.2<br>22.2 | 5.4<br>6.3 | –0.382 | 0.707 | –6.5 | 4.5 |
| **LFH** | 44.8 | 3.9 | Male<br>Female | 45.8<br>43.8 | 4<br>3.6 | 1.165 | 0.039+ | –1.6 | 5.6 |
| **MB** | 40 | 10.9 | Male<br>Female | 45.4<br>34.6 | 12.9<br>4.6 | 2.496 | 0.022+ | 1.7 | 19.9 |
| **Gon–A** | 125.3 | 5.8 | Male<br>Female | 124.6<br>125.9 | 5.3<br>6.5 | –0.492 | 0.628 | –6.8 | 4.2 |
| **SpPA** | 128.5 | 4.6 | Male<br>Female | 128.8<br>128.2 | 4.4<br>5 | 0.284 | 0.780 | –3.8 | 5 |
| **PO–N–ANS** | 80.9 | 4.4 | Male<br>Female | 80.9<br>80.9 | 4.7<br>4.3 | 0.000 | 1 | –4.2 | 4.2 |
| **OP–NS** | 11.9 | 4.2 | Male<br>Female | 10.8<br>12.9 | 3.7<br>4.7 | –1.113 | 0.280 | –6.1 | 1.9 |
| **OP–FH** | 4.3 | 4.3 | Male<br>Female | 3.0<br>5.4 | 4.5<br>4 | –1.21 | 0.242 | –6.3 | 1.7 |
| **OP–PP** | 4.9 | 3.3 | Male<br>Female | 4.1<br>5.7 | 3.4<br>3.1 | –1.093 | 0.289 | –4.7 | 1.5 |
| **Op–MP** | 17.2 | 3.3 | Male<br>Female | 17<br>17.4 | 3.4<br>3.4 | –0.263 | 0.796 | –3.6 | 2.8 |

+ Significant difference at $p < 0.05$; ++ Variables were measured in degrees; * Number of sample: 20; ** Number of sample: 10; SD: Standard deviation; LL: Lower limit; UL: Upper limit; CI: Confidence; interval.; FH: Frankfort horizontal plane; PP: Platal plane; MP: Mandibular plane; LFH: Lower facial hight; MB: Mandibular bend angle; Gon: Gonion; SpPA: Soft palate palatal plane angle; A: Subspinale; Po: Porion Op: Occlusal plane; N: Nasion; S: Sella; A: Subspinale;

Table (5) showed no significant differences presents at $p \leq 0.05$ of the angles made by the natural occlusal plane and each of the superior, middle and inferior ala–tragus lines. The negative mean values indicated the anterior convergence of the ala–tragus lines with occlusal plane. The values of (OP.AT) angles (Figures 5, 6) become smaller as the ala–tragus line moved inferiorly.

Table (5): Descriptive statistics for angular measurements of OP.AT angle in the total group I

| Variables | Total Mean* | ± SD | Sex** | Mean | ± SD | t–test | | 95% CI | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | t–value | *p*–value | LL | UL |
| **OP–AT1** | –8.2 | 6.2 | Male<br>Female | –7.2<br>–9.2 | 8.4<br>3 | 0.709 | 0.487 | –3.9 | 7.9 |
| **OP–AT2** | –.52 | 4.5 | Male<br>Female | –4.9<br>–5.5 | 5.8<br>2.8 | 0.292 | 0.773 | –3.7 | 4.9 |
| **OP–AT3** | 1.2 | 2.8 | Male<br>Female | 1.4<br>1 | 3.4<br>2.4 | –0.307 | 0.762 | –3.1 | 2.3 |

* Number of sample: 20; ** Number of sample:10; SD: Standard deviation; LL: Lower limit; UL: Upper limit; CI: Confidence interval; OP: Occlusal plane; AT : Ala–tragus lines

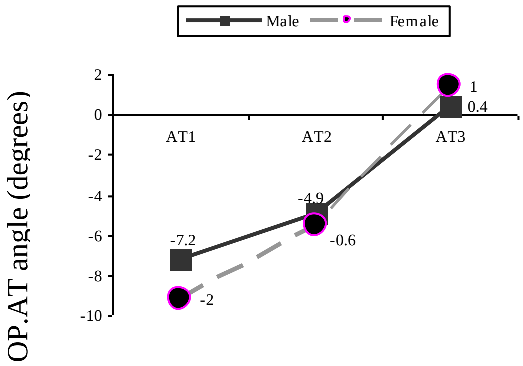


Figure (5): Comparison between males and females in the degree of angulation of the three ala–tragus lines with natural plane in group I.

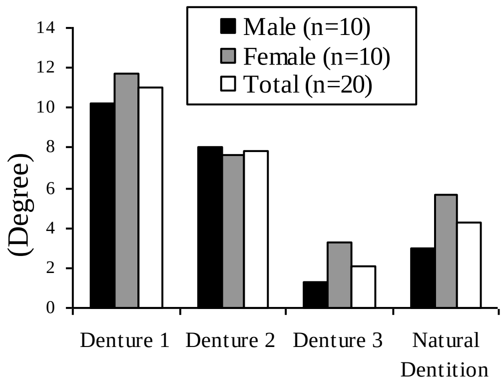


Figure (6): Comparison between the angulation of the three ala–tragus lines of group I and that of the occlusal plane in relations to Frankfort horizontal plane

Tables (6, 7) illustrated the means and deviations in the position of each ala–tragus line around the natural occlusal plane and the angular measurements of (FH.AT) angle in total group I.

Table (6): Descriptive statistics for angular measurements of FH.AT angle in the total group I

| Variables | Total Mean* | ± SD | Sex** | Mean | ± SD | t–test | | 95% CI | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | t–value | *p*–value | LL | UL |
| **FH–AT1** | 10.9 | 2.4 | Male<br>Female | 10.3<br>11.5 | 2<br>1.5 | –0.335 | 0.771 | –4.9 | –1.5 |
| **FH–AT2** | 7.8 | 1.9 | Male<br>Female | 7.9<br>7.6 | 2.5<br>1.3 | 0.342 | 0.736 | –1.5 | 2.1 |
| **FH–AT3** | 2.4 | 2.3 | Male<br>Female | 1.4<br>3.3 | 2.7<br>1.3 | –2.009 | 0.06 | –3.9 | 8.7 |

* Number of sample: 20; ** Number of sample:10; SD: Standard deviation; LL: Lower limit; UL: Upper limit; CI: Confidence interval; FH: Frankfort horizontal plane; AT : Ala–tragus lines

Table (7): Comparison of the occlusal plane cant (OP.FH angle) between the totals of group I and group II

| Group I | | Group II | | | t–test | |
|---|---|---|---|---|---|---|
| Mean ± SD | Number | Denture Number | Mean ± SD | Number | t–value | *p*–value |
| 4.3±4.3 | 20 | 1 | 11.3±3.7 | 20 | 5.565 | <0.001** |
| | | 2 | 5.4±3.7 | 20 | 0.901 | 0.373 |
| | | 3 | –0.3±4.5 | 20 | –3.265 | 0.002* |

* Significant difference at $p$–value ≤ 0.01; ** Significant difference at $p$–value ≤ 0.001; SD: Standard deviation

The three artificial occlusal plane cants that were constructed to be parallel to the ala–tragus lines in group II were compared with the natural occlusal plane cant in group I to investigate where the difference exists (Figures 7–8).

The results of application of the new program were shown through the ability of running to determined digital colour density of the soft and skeletal structures for each clinical case, planes, and measured six cephalometric angles obtained by "CoDiC" program were compared with those obtained by the conventional method (Figure 4). These results show no significant difference between the two methods at $p \leq 0.05$.

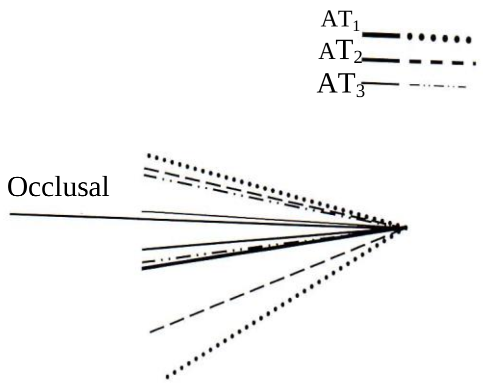


Figure (7): The means and standard deviations for the angles between the natural occlusal plane and the three ala–tragus lines

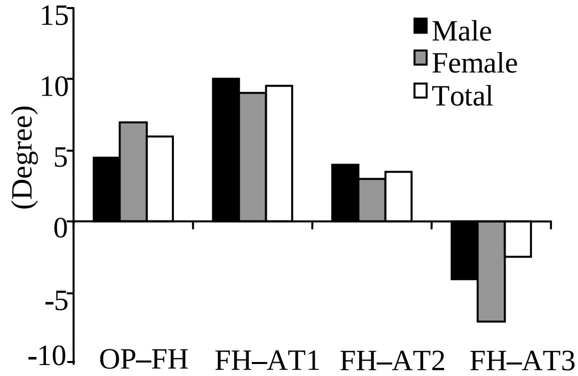


Figure (8): Comparison between the angulation of the three ala–tragus lines of group I and that of the occlusal plane in relations to Frankfort horizontal plane.

Standard deviations and standard error of deviations of four of these measurements of computerized method appear to be larger than those of conventional method (Table 8).

Table (8): Comparison between computerized and conventional analysis.

| Variables | Computerized Method | | Conventional Method | | t–test | |
|---|---|---|---|---|---|---|
| | Mean ± SD | Number | Mean ± SD | Number | t–value | *p*–value |
| **OP–AT1** | –8.4±7.2 | 20 | –8.2±6.2 | 20 | 0.344 | 0.735 |
| **OP–AT2** | –5±4.4 | 20 | –5.2±4.5 | 20 | 0.428 | 0.688 |
| **OP–AT3** | –1.2±2.4 | 20 | –1.2±2.8 | 20 | 0.466 | 0.647 |
| **FH–AT1** | 12±2.6 | 20 | 11.9±2.4 | 20 | 1.590 | 0.138 |
| **FH –AT2** | 7.5±2.1 | 20 | 7.8±1.9 | 20 | 0.398 | 0.704 |
| **FH–AT3** | 2.4±2.4 | 20 | 2.4±2.3 | 20 | 0.061 | 0.943 |

SD: Standard deviation; OP: Occlusal plane; AT : Ala–tragus lines; FH: Frankfort horizontal plane

## DISCUSSION

As all the measurements in this study were made on cephalometric radiographs taken on the same machine, errors in measurements resulting from magnification were insignificant (Table 1). Any variable has an effect on the cephalometric measurements formed by the occlusal plane could affect the orientation of the occlusal plane itself.

*Angular Measurements*: Maxillary Depth Angle showed a significant negative correlation with (OP.FH) (Table 2). This means that higher maxillary depth angle is usually associated with less inclined occlusal plane cant. Mandibular Depth Angle is also named the facial angle. This angle gives an indication of the anteroposterior position of the chin.[19]

There was significant negative correlation between this angle and the (OP.FH) angle (Table 3) which means that as the mandibular depth angle increases, the (OP.FH) angle decreases; i.e., the occlusal plane becomes less inclined posteriorly. This result is in consistence with other studies.[2,6,8,22]

FH.MP Angle showed high significant positive correlation with the (OP.FH) and (OP.MP) angles (Table 2). This indicates that a large mandibular plane (MP) angle is usually associated with steeply inclined occlusal plane in relation to the Frankfort horizontal and mandibular planes respectively.[8, 22]

FH.PP Angle has strong positive correlation with OP.FH angle (Table 2) which means increasing palatal plane (PP) cant relative to Frankfort horizontal plane is usually associated with increasing occlusal plane cant relative to the same reference plane.

PP.MP Angle represented the angle of the denture space or the maxillo–mandibular space, and in edentulous patients showed slightly lower mean value (21.2± 4.2)°. This may indicate the occurrence of reduced vertical dimension as a result of edentulism.(3) In dentulous subjects, this angle shows significant positive correlateion with (OP.FH), (OP.PP) and (OP.MP) angles (Table 2).(6, 22)

L.F.H. Angle showed significant positive correlation with each of (OP.FH), (OP.PP) and (OP.MP) angles (Table 2) in dentulous,(23) while in edentulous patients this angle shows slightly lower mean value (42± 3.9)° (Table 3). Mandibular Bend Angle showed significant negative correlation with (OP.PP) angle which means that as the bend of the mandible becomes more prominent, the occlusal plane moves to be nearly parallel to the palatal plane (Table 2). In edentulous group, this angle showed slightly larger mean values than dentulous group (41.8 ± 12.7)°.

Several studies have reported that face shape partly depends on the strength of the muscles. Ogawa *et al*.,(25) stated that both the force and the direction of the muscle especially the masseter muscle may possibly contribute to the shape of the mandibular border which, in turn, influences the formation of the inclination of the occlusal plane.

Gonial Angle has high significant positive correlation with the (OP.NS), (OP.PP) and (OP.MP) angles (Table 2).(24) In edentulous group, this angle showed slightly larger value than dentulous group (Table 3).This correlation may be due to the fact that both angles give the relationship of the occlusal plane to the upper base.(25)

The mean value of OP.FH Angle for the dentulous subjects was 4.3 ± 4.3° (Table 4). For edentulous group, the occlusal plane cant angle of the second denture showed the nearest mean value 5.4 ± 3.7° among the other artificial occlusal planes to the natural one (Table 3). While The $OP.FH_1$ Angle of the first denture showed very high mean value reaches 11.3 ± 3.7° (Table 3). This value is near to that obtained by Younis.(26) In both studies this artificial occlusal plane was placed at a higher level posteriorly as compared with the natural occlusal plane.

$OP.FH_3$ Angle of the third denture showed a small negative mean value (Table 3). This indicates that the posterior terminates of this artificial occlusal plane was placed too much inferior to that of natural one.

OP.PP Angle represented the indication of the occlusal plane in relation to the maxillary base. In edentulous patients and as shown in Tables (3,4), the $OP.PP_2$ and $OP.PP_3$ angles have nearer mean values 6.8 ± 5.1 and 3.3 ± 2.1 degrees respectively than that of $OP.PP_1$ angle. This indicated that the natural occlusal plane seems to be located between the middle and inferior artificial occlusal planes in relation to the palatal plane.(8)

OP.MP angle represented the inclination of the occlusal plane in relation to the mandibular base showed mean values of 5 ± 3.3°, 9 ± 3.2° and 13.6 ± 3.8° for the first, second and third dentures respectively (Tables 2, 3). All the three OP.MP angles present in edentulous patients are smaller than that with natural dentition (Table 4). This may be due to the reduced vertical dimension reported with the edentulous group.(25) This angle does not show significant correlation with any of the angles formed by the intersection of the occlusal plane and other skeletal planes (Table 2).

*Ala – tragus Line Relations*: In young dentulous subjects, the most valid ala–tragus to be used as an index of the occlusal plane inclination is the inferior one which extends from the lower border of the ala of the nose to the inferior border of the tragus of the ear. Table (5) showed that no one of the three ala–tragus lines (superior, middle and inferior) appears to be exactly parallel to the natural occlusal plane on the average. Instead the natural occlusal plane forms angles with the plane.(8, 27)

The closest ala–tragus line in relation to the natural occlusal plane of young adults is the inferior one. This is in disagreement with other studies(8, 10, 27) that considered the middle ala–tragus to be closest to the occlusal plane (Figures 4, 5).

The $OP.AT_3$ angle has constant relationship with other craniofacial measureements more than $OP.AT_1$ and $OP.AT_2$ angles. This will enhance the validity of using the inferior ala–tragus line as a guide of the occlusal plane inclination. Figure (7) showed the magnitude of the variation of the three ala–tragus lines in their angles with the natural occlusal plane.

In the dentulous subjects, the three ala–tragus lines (superior, middle and inferior) intersect Frankfort horizontal plane with posterior convergence forming angles of mean values $10.9 \pm 2.4°$, $7.8 \pm 1.9°$ and $2.4 \pm 2.3°$ respectively (Table 6). In edentulous patients, the three ala–tragus lines appeared to have lower positions than those in dentulous subjects and the superior and middle ala–tragus lines have posterior convergence while the inferior one has anterior convergence (Figure 8).

In edentulous patient, this plane could be placed between these two lines but more closely to the middle one. The auricle increases dimensionally throughout the individual's life. In senility, when this continued growth is combined with the shrinking of the tissues in other parts of the face, a tremendous change results in the general facial contour of the individual.[28]

The three artificial occlusal planes were oriented to be parallel to the three ala–tragus lines as proposed in the method carried out in this study. Therefore, the comparison between OP.AT angles in edentulous patients was unreasonable. The three artificial occlusal planes in edentulous patients were compared with the natural occlusal plane in their relations to Frankfort horizontal plane as a common, unchangedable reference plane. As illustrated in Table (7), the mean values of the OP.FH angles of dentulous and edentulous groups explained that the $OP.FH_2$ angle in edentulous group is the nearest one to the OP.FH angle of dentulous group. This indicated that the closest artificial occlusal plane to the natural is that of the second denture which is oriented to be parallel to the middle ala–tragus line (Figure 6).

The program CoDiC gave a successsful and faster results of direct accurate determination of the soft and skeletal tissues to the conventional cephalometric method. In comparison of the measurements obtained by program for computerized digitization of cephalometric radiograph with those obtained by the conventional method, the difference between the two groups was statistically insignificant at $p \leq 0.05$. This enhances the validity of the program for cephalometric analysis.[28.29]
Interest should be directed toward the standard deviation of values from their means. The standard deviations of measurements performed by computerized program were found to be little more than that found by using the conventional method. The computerized analysis was per–formed on a digitized image with specific resolution, while the conven–tional method was done using the original radiographs. Authors[15] reported that the observer error in landmark identification in digital image was generally larger than that in the original radiograph (Figure. 9).

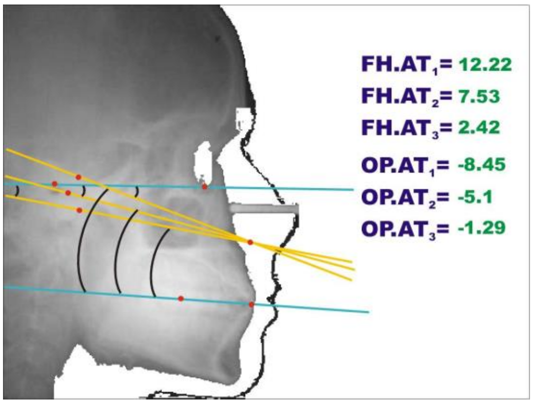


Figure (9): Digital determination of angles, planes, soft and skeletal tissues by CoDiC program (Clinical case).

## CONCLUSIONS

There is a strong relationship between the occlusal plane and other craniofacial measurements especially those determineing skeletal jaw relationship (maxillary depth, facial and Frankfort mandibular plane angles) and those determining facial types (facial, lower facial, mandibular bend and Frankfort mandibular plane angles).

In natural dentition, the occlusal plane does not have exact parallelism with three different levels of ala–tragus line. Instead, the occlusal plane appears to be parallel to ala–tragus line extending from the inferior border of the ala of the nose to a point intermediately located between the middle and inferior points of the tragus of the ear with more approximation to the inferior border. This result was coinciding with complete dentures constructed for edentulous patients cephalometrically.

Computer program was designed to analyze digital cephalometric radiographs. Its validity had been proved statistically by comparing its measuring of 6 angles formed between the three ala–tragus lines with each of Frankfort horizontal and occlusal planes.

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