The relationship of occlusal plane orientation and facial height

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Abstract

Correct occlusal plane orientation in complete denture construction is critical for the denture stability, esthestics, phonetics, masticatory function and facial harmony.. Various techniques are being practiced for the orientation of occlusal plane but each method advocated has its own limitations. This present study aimed to determine the location of anterior occlusal plane in relation to inner canthus and the location of posterior occlusal plane in relation to outer canthus as fixed reference points and to find the relationship between inner canthus-anterior occlusal plane distance (Ic-Op), outer canthus-posterior occlusal plane distance (Oc-Op) and facial height in dentate subjects. A total of 264 subjects (132 male and 132 female) with class I occlusion aged 21 - 30 years' students and staff of the University of Dental Medicine, Mandalay. Anthropometric measurements of facial height, Ic-Op (inner canthus-anterior occlusal plane distance) and Oc-Op (outer canthus-posterior occlusal plane distance) were measured clinically using modified digital caliper (Guanglu, 10-300 mm). Data were analyzed using simple linear regression test. There was positive and strong correlation between facial height and Ic-Op in total population [r = 0.718] and male group[r = 0.642] with a high statistical significance (P < 0.001) while there was positive and moderate correlation in female [r = 0.508]. It was also found that facial height was significantly (P < 0.001) and positively correlated with Oc-Op in total population [r = 0.663], male [r = 0.641] and female [r = 0.463] respectively. A linear regression analysis was used to formulate a general equation to predict the Ic-Op and Oc-Op distance from the facial height measurement (Ic-Op = 12.09 + 0.29 x FH and Oc-Op = 25.2 + 0.23 x FH). Based on the analyzed data, the resultant regression equation would be used to predict the location of anterior and posterior occlusal plane in edentulous patients by using facial height.

Introduction

The Glossary of Prosthodontic Terms (GPT-9)defines occlusal plane as "the average plane established by the incisal and occlusal surface of the teeth". [1] The position of the occlusal plane orientation forms the basis for ideal tooth arrangement and should fulfill fundamental requirements such as esthetic, phonetics, mastication and comfort. [2]

Where all natural teeth have been lost, the prosthodontists concerned with the provision of the first complete denture has less reliable indicators. The guides in use are often remote from the position of the occlusal plane, diffuse, poorly defined (in both the physical and literal senses) and inconstant.[3] Most of the studies regarding the establishment of artificial occlusal plane in edentulous patients advocate placement of the artificial teeth in a natural position which enhances denture stability and

functional value.

Changes in the plane of occlusion will modify the physical and functional relationship of the oral musculature leading to an alteration in function, comfort and the esthetic value. Madhav (2015) stated that "If occlusal plane is placed too high, tongue cannot rest on the lingual cusp of mandibular denture and prevent its displacement. There is also a tendency for accumulation of food in buccal and lingual sulci. On the other hand if the occlusal plane is too low, it will lead to tongue and cheek bite."[4] Therefore, position and orientation of the occlusal plane is important in both natural and artificial dentitions.

The accurately locating the occlusal plane is one of the most important steps in prosthetic treatment of edentulous patients. The level of the occlusal plane has been established in various concepts: (i) locating it parallel to and midway between the residual ridges (Nagle & Sears, 1962); (ii) locating it below the resting upper lip anteriorly and parallel to the Camper line posteriorly (Lejoyeux, 1967); (iii) positioning of the occlusal plane on the same level as the lateral border of the tongue (Landa, 1957 and Yasaki, 1961); (iv) locating it posteriorly at the middle or upper third of retromolar pad (Ismail, 1968); (Hickey & Zarb, 1980) ; (v) relating the occlusal plane to the parotid papilla (Foley & Latta, 1985)and (vi) relating the occlusal plane to hamular notch- incisive papilla (HIP) (Thapa, 2014). But, the clinical experience has shown that the position of the occlusal plane in many denture wearers does not coincide with the above principles.[5, 6, 7]

A common concept is that the anterior occlusal plane should parallel to the inter-pupillary line and should locate 1-3 mm below the resting upper lip and the posterior occlusal plane should parallel to the alar-tragus line. But which line of tragus to be used is still questionable: inferior margin of tragus (Hartono, 1967), midpoint of tragus (Nikzad, 1974), superior border of tragus(Trapozzano, 1955).[8, 9, 10] Furthermore, according to Misch (2008), determining the orientation of the occlusal plane according to the upper lip as a guide for occlusal plane orientation is unreliable. He did a study on guideline for maxillary incisal edge position and found that average central incisor exposure in relation to the relaxed upper lip line was -1 to +8 mm and therefore upper lip could not be used as a guide to access the incisal edge position. It is necessary to find a fixed reference point to determine location of anterior occlusal plane and orientation of posterior occlusal plane.[11]

Some authors suggested that there is a relation between occlusal plane orientation and facial proportions. Brodie (1941) assumed that the face swings out from under the cranium with advanced age, and that great changes can take place in the facial structure during growth, which may have a marked influence on occlusion.[12] Ahmad, Jawad, & Al–Ali (2006) mentioned that there may be probable differences between the orientations of occlusal plane in different vertical facial proportions.[13] Arnett (2010) stated 'The bite indicates a problem; the face indicates how to treat the bite'.[14] None of these studies reported detail about the degree of correlation between facial height and occlusal plane.

Therefore, the present study aimed to determine the location of anterior occlusal plane in relation to inner canthus and the location of posterior occlusal plane in relation to outer canthus as fixed reference points and to find the relationship between inner canthus-anterior occlusal plane distance, outer canthus-posterior

occlusal plane distance and facial height in dentate subjects.

From this study, the relationships between facial heights with inner canthus-anterior occlusal plane distance, outer canthus-posterior occlusal plane distance were determined. The results of this study were expected to provide important information regarding relationship between facial height and occlusal plane orientation. So that it might be clinically applicable to determine the location and orientation of anterior occlusal plane and posterior occlusal plane in complete denture construction and occlusal rehabilitation.

Materials and methods

Before initiating the survey, a pilot study was conducted on sixty subjects to set the objectives and to check the feasibility of the study. Based on the results of the pilot study, the sample size was determined keeping the significance level and power of the study at 5% and 80% respectively. A total of 264 dentate subjects (132 male and 132 female) that included staff and students were randomly selected from the University of Dental Medicine, Mandalay. Inclusive criteria from the sample were: aged between 21-30 years old; a full dentition set (except third molar), class I jaw relation. Those subjects with crowns, fixed or removable partial dentures, supernumerary teeth, TMJ disorders, history of trauma and history of orthodontic or orthognathic surgery were excluded. Nature of the study was explained with subject information sheet and an informed consent of all the subjects was obtained.

The three parameters, FH (facial height), Ic-Op and Oc-Op of each subject were measured with a digital vernier caliper (Guanglu, China Ltd.,). Each participant was seated in upright position with his/her eyes looking straight forward and his/her mandible was in rest position. The rest position of mandible was confirmed by accepted prosthodontics principles. Anthropological measurements were made by dots and strips marked on the adhesive tape on each participant's face at determined points. The facial height were obtained by measuring the distance between trichion (point where the hair line meet the center of forehead) and menton (the lowest point of the chin in the center line) with the help of digital slide caliper (GuangLu, 10-300mm). Measurements were taken three times with five minutes resting interval and recorded in millimeter with two decimals. For all measurements, measurements were taken at the same time of the day (in the morning).

The Ic-Opis the distance from mid intercanthal point to mesio-incisal edge of permanent maxillary central incisor while the Oc-Op is the distance from outer canthus to mesio-palatal cusp of maxillary permanent first molar.These two measurements were measured with digital slide caliper (GuangLu, 10-300mm). Measurements were done on both left and right sides. Measurements were taken for each side and recorded in millimeter with two decimals and their mean were calculated. The data were statistically analyzed with use of the simple linear regression test at $P< 0.05$.

Results

In this study, total number of subjects was 264 (staff, students and house officers at University of Dental Medicine, Mandalay). Total of 50% (132) were male and the other 50% (132) were female. Firstly, Kolmogorov Smirnov test was used to test for normality of distribution of the collected data and all the three parameters

were a normally distributed data. Then, the descriptive statistics of the parameters (facial height, Ic-Op distance, Oc-Op distance) for the total population, male, female were presented in table 1.

Table 1. Descriptive statistics of facial height, mid inner canthus-anterior occlusal plane distance (Ic-Op), outer canthus-posterior occlusal plane (Oc-Op)

Variables		Mean ± SD (mm)	Min (mm)	Max (mm)
Total	FH	183.58 ± 10.59	156.23	218.17
	Ic-Op	64.69 ± 4.2	53.67	75.64
	Oc-Op	68.02 ± 3.73	60.07	78.29
Male	FH	189.28 ± 9.49	156.23	218.17
	Ic-Op	67.05 ± 3.48	54.94	76.58
	Oc-Op	69.57 ± 3.67	61.06	78.29
Female	FH	177.88 ± 8.34	158.27	197.42
	Ic-Op	62.16 ± 3.41	53.67	71.27
	Oc-Op	66.39 ± 3.09	60.07	74.33

SD = standard deviation

The mean FH (facial height) of all subjects was 183.58 mm with a range of 156.23 mm – 218.17 mm. The mean Ic-Op (inner canthus – anterior occlusal plane distance) of all subjects was 64.69 mm with the range of 53.67 mm – 75.64 mm while the mean of Oc-Op (outer canthus – posterior occlusal plane distance) of all subjects was 68.02 mm with the range of 60.07 mm – 78.29 mm. The mean FH (189.28 mm) of male with the range of 156.23 mm – 218.17 mm whereas the mean FH of female was 177.88 mm with the range of 158.27 mm – 197.42 mm. And the mean Ic-Op (67.05 mm) of male with the range of 54.94 mm – 76.58 mm while the mean of Ic-Op (62.16 mm) of female with the range of 60.07 mm – 78.29 mm. Then, the mean Oc-Op of male group was 69.57 mm with the range of 61.06 mm – 78.29 mm whereas the mean Oc-Op of female group was 66.39 mm with the range of 60.07 mm – 74.33 mm.

Pearson's correlation was used to correlate the relationship of facial height with Ic-Op and Oc-Op for total population, male and female respectively.

Table 2. Correlation matrix between facial height and inner canthus-anterior occlusal plane (Ic-Op) distance

Variables	FH	
	r	P value
Ic-Op (Total)	0.718	< 0.001
Ic-Op (male)	0.642	< 0.001
Ic-Op (Female)	0.508	< 0.001

Table 3. Correlation matrix between facial height and outer canthus-posterior occlusal plane (Oc-Op) distance

Variables	Facial Height	
	r	P value
Oc-Op (Total)	0.663	< 0.001
Oc-Op (male)	0.641	< 0.001
Oc-Op (female)	0.463	< 0.001

The coefficient of correlation [r] by Pearson's method between the Ic-Op and facial height, at the probability level of 95% was presented in table 2. From table 2, it was found that facial height was positive and "strong" correlation with Ic-Op in total population [r = 0.718] and male [r = 0.642] respectively with a high statistical significance (P < 0.001) whereas facial height was positive and "moderate" correlation with Ic-Op in female [r = 0.508] with a high statistical significance (P < 0.001).

The coefficient of correlation [r] by Pearson's method between the Oc-Op and facial height was also presented in table 3. From table 3, it was observed that there was significantly correlation between facial height and Oc-Op in total population [r = 0.663], male [r = 0.641] and female [r = 0.463] respectively. Hence, regression analysis was performed for prediction of dependent variables (Ic-Op and Oc-Op) using facial height.

The regression relationship between facial height and dependent variables (Ic-Op and Oc-Op) of total population, male and female were initially evaluated from scatter plots.

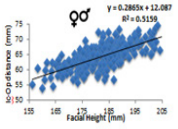
Figure 1. Linear regression: Predicting Ic-Op distance using facial height (Total)

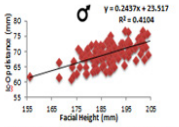
Figure 2. Linear regression: Predicting Ic-Op distance using facial height (Male)

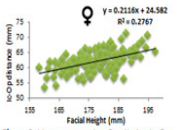
Figure 3. Linear regression: Predicting Ic-Op distance using facial height (Female)

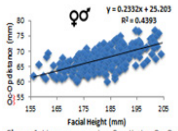
Figure 4. Linear regression: Predicting Oc-Op distance using facial height (Total)

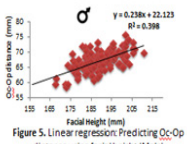
Figure 5. Linear regression: Predicting Oc-Op distance using facial height (Male)

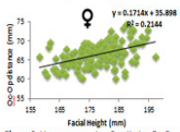
Figure 6. Linear regression: Predicting Oc-Op distance using facial height (Female)

Table 4 contains prediction table for Ic-Op based on the facial height. These values were derived using the regression equation y = a + bx. For the Ic-Op, x = facial height, a = 12.09 for total population, 22.24 for male and 25.28 for female, b = 0.29 for total population, 0.24 for male and 0.21 for female. Determination of Ic-Op using regression equation facial height had a standard error of 2.95 (total population), 2.84 (male) and 1.94 (female). The 95% confidence interval for "b" was 0.253, 0.230 (Total), 0.188, 0.286 (Male) and 0.152, 0.271 (Female). Therefore, the regression equation was y = 12.09 +0.29x (total population),y = 22.24 + 0.24x (male) andy = 25.28 + 0.21x (female).

From table 4, it was observed that the coefficient of determination (r2) was 0.516 (total population), 0.412 (male) and 0.258 (female) respectively.

Table 4. Regression: Predicting Ic-Op distance using facial height

Model	a	b (95% ci)	SEE	r^2
Ic-Op (Total)	12.09	0.28 (0.253-0.230)	2.95	0.516
Ic-Op (Male)	22.24	0.24 (0.188, 0.286)	2.84	0.412
Ic-Op (Female)	25.28	0.21(0.152, 0.271)	2.94	0.258

SEE – Standard error of the estimate, P value - < 0.001

Table 5 contains prediction table for Oc-Op based on the facial height. These values were derived using the regression equation y = a + bx. For the Oc-Op, x = facial height, a = 25.2 for total population, 23.52 for male and 35.9 for female, b = 0.23 for total population, 0.24 for male and 0.17 for female. Determination of Oc-Op using regression equation facial height had a standard error of 2.95 (total population), 2.84 (male) and 1.94 (female). The 95% confidence interval for "b" was 0.201, 0.265 (Total), 0.193, 0.294 (Male) and 0.114, 0.228 (Female). Therefore, the regression equation was y = 25.2 +0.23x (total population),y = 23.52 + 0.24x (male) andy = 35.9 + 0.17x (female).

From table 5, it was observed that the coefficient of determination (r2) was 0.439 (total population), 0.410 (male) and 0.214 (female) respectively.

Table 5. Regression: Predicting Oc-Op distance using facial height

Model	a	b (95% ci)	SEE	r^2
Ic-Op (Total)	25.2	0.23(0.201, 0.265)	2.80	0.439
Ic-Op (Male)	23.52	0.24(0.193, 0.294)	2.78	0.410
Ic-Op (Female)	35.9	0.17(0.114, 0.228)	2.75	0.214

SEE – Standard error of the estimate, P value - < 0.001

Discussion

The sample for the present study was selected from 21-30 years old of staff, students and house officers from University of Dental Medicine, Mandalay who satisfied the inclusion criteria. The choice of the subjects was from University of Dental Medicine, Mandalay because they are familiar with dental knowledge and terminology such as rest position and occluded contact position etc. Therefore, by sampling from these subjects, it was assumed

that reasonably reliable measurements could be obtained.

In this study, the subjects belonged to 21-30 years age group. Experts assumed that most bones in the body including the human skull stop growing after puberty. Some males only grow until about 16 years of age and other grow until they are in early 20. On the other hand, the female jaw reaches its greatest growth to an adult state between the age of 12 and 15 and most females stop growing by about the age of 18. Therefore, 21-30 years age group was selected because within these ages, growth of body has completed proportionally and all the teeth are erupted at level of occlusal plane. After being older than 30 years of age, there is increasing chance of attrition of teeth, which can cause alteration of level of the occlusal plane.

The reliability of the measurements is one of the most important aspects of anthropological studies. Anthropometric measurements have been shown high reliability. Making landmarks on the skin prior to taking measurements has been recommended and was shown to have a significant effect on reliability of anthropometric measurements. Studies done by Farkas (1994) and Shaner (1998) have found high levels of anthropometric reliability of the face, most measurements varying less than 1 mm on repeated measurements.[15, 16] Chu (1989), Ghoddousi (2007) and Mollov, et al., (2012) found high intra-examiner reliability. [17, 18] In this study, the intra-class correlation coefficient (ICC) were 0.997 (facial height), 0.990 (Ic-Op) and 0.973 (Oc-Op) respectively. Referring above data, the measurements performed in the present study were considered reliable and within the acceptable range.

Different points are used by different workers to define the occlusal plane in natural dentition. In this research, the choice of an occlusal plane extending from the midincisal point of the upper central incisors to the mesiopalatal cusps of the maxillary first molar was also prompted by prosthetic reasons. The occlusal plane is that on which prosthetic teeth are most commonly arranged during denture construction.[19]

In this study, all measurements were taken at the same time of the day (in the morning) because environmental factor can also affects the accuracy of vertical dimension. If the weather is very hot and measurement of vertical dimension is taken in the afternoon, atmospheric temperature was highest at this time. It may cause the subject to feel uncomfortable to participate. Therefore, the accurate rest vertical dimension cannot be readily achieved.

After each measurement, the subject was taken out of the chair and given time to relax before the second time measurement was started. By providing a rest period (5 minutes interval), it would decrease the possible factor of fatigue from influencing the results of the study. Moreover, such a short resting period is ideal since there may be possible changes in facial dimensions over an extended period of time due to environmental factors, such as body mass index, temperature and humidity. These environmental factors may cause measurable soft tissue changes that affect reliability of quantifying the measurements.[15]

Before measuring the facial height, the subjects were asked to comfortably seat in the chair and asked to relax the whole body as completely as possible and allow the jaw to rest in a neutral position with the lips closed. Measurements were taken at rest position because the original vertical dimension is no longer preserved when a person becomes

edentulous (Miljkovic, et al., 2001). Unlike the occlusal vertical dimension, the mandibular rest position was originally believed to be established at birth and maintained throughout life. [20]

In this study, the Pearson's correlation coefficient for facial height and Ic-Op was found to be positive, "strong" and highly significant at the 0.001 level in total population [r = 0.718] and male [r = 0.642] respectively whereas facial height was positive and "moderate" correlation with Ic-Op in female [r = 0.508] with a high statistical significance (P < 0.001). It was also found that the Pearson's correlation coefficient for facial height and Oc-Op was positive, "strong" and highly significant in total population [r = 0.663] and male[r = 0.641] respectively with a high statistical significance (P < 0.001) whereas relationship between facial height and Oc-Op in female was positive and moderate [r = 0.463] with a high statistical significance (P < 0.001). Therefore, there is sufficient evidence to suggest that the true population correlation coefficient is not 0 and that there is a linear relationship between facial height and Ic-Op/Oc-Op.

It was found that the Pearson's correlation coefficients for facial height and Ic-Op as well as Oc-Op were significantly decreased in female samples.

These variations may be because within female, there is a layer of subcutaneous fat that causes the rounding and softening of contours of the face and inaccuracies may also arise from variable pressures on soft tissue landmarks during measurement. In contrast, male subcutaneous fat development is much less pronounced due to the effects of testosterone which reduces fat by aiding fast metabolism which gives the male a leaner and more angular face than the female. [21] Although there was a variation in female samples, there was still a correlation between the facial height and Ic-Op/Oc-Op.

The coefficient of determination, an indicator of the predictive accuracy of the regression equation, for facial height and Ic-Op was found to be 0.516 (total population), 0.412 (male) and 0.258 (female) respectively. This means that 52 % of variation of Ic-Op was accounted by knowing facial height while 41% and 26% of Ic-Op were explained by facial height in male and female. In the present study, the Ic-Op (total population) exhibited higher coefficient of determination values than both Ic-Op (male) and Ic-Op (female). Therefore, y = 12.09 + 0.29 x was the most suitable equation for orientation of the anterior occlusal plane in edentulous patient.

The coefficient of determination (r2) for facial height and Oc-Op was found to be 0.439 (total population), 0.410 (male) and 0.214 (female) respectively. In the present study, the Oc-Op (total population) exhibited higher coefficient of determination values than both Oc-Op (male) and Oc-Op (female). Therefore, y = 25.2 + 0.23 x was the most suitable equation for orientation of the antero-posterior occlusal plane in edentulous patient.

In this study, the relationship between facial height and Ic-Op was found to be more consistent than those of the relationship between facial height and Oc-Op. Based on this finding, it can be postulated that there may be different patterns of occlusal plane inclination (occlusal plane angle). These discrepancies of antero-posterior inclination of occlusal plane with other reference planes were also reported in other studies done by various authors. A cephalometric study done by van Niekerk, et al., (1985) on 33 edentulous patients, found

the angulations of occlusal plane to Camper's plane as 3.45˚ whereas Koller, et al., (1992) and Karkazis & Polyzois (1987) reported it as 7.00˚ and 10.00˚ respectively.[22, 23, 24] Seifert, et al., (2000) has concluded occlusal plane-FH plane angulations as 11.42˚ in dentulous subjects whereas Celebic, et al., (2009) proposed it as 9.43˚ and 8.53˚ in dentulous and edentulous subjects.[25] Moreover, Kuldeep, Nandeeshwar, Rudraprasad, & Kumar (2014) carried out a study to analyze the relation between camper's plane and natural occlusion plane in Indian dentulous subjects by using Fox plane. It was concluded that there may be various kinds of occlusal plane inclination and may be associated with different horizontal and vertical growth patterns of an individual.[26]

The advantages of this study are simple, non-invasive method with no radiation exposure to the subject compared with cephalometric study. Calculation of Ic-Op and Oc-Op from using facial height and expressed in the formulate equation could be a new method of the occlusal plane determination which can be applied in edentulous patients. The results can be tabulated for faster orientation of the occlusal plane in edentulous patients in daily practice.

The limitation of this study is that only class I normal occlusion was considered in the present study. Other types such as class II, class III malocclusion were not taken into consideration. Variations in the measurements may be due to the differences in measuring ethnicities of the population and sample size studied. Hence, further research for each ethnicity is necessary to confirm its applicability in different populations before deriving an appropriate regression equation which can be accepted universally. In some edentulous patients, hair line may not be well demarcated. In this situation, it is impossible to take the measurements. Another study should be focused on other reliable fixed reference point.

Conclusion

In this particular population, there was strong and positive correlation between facial height with Ic-Op and Oc-Op distances. The resulted linear regression formula would be used to determine anterior and posterior occlusal plane by measuring the facial height and by using inner canthus and outer canthus as fixed reference points. In edentulous patients, this method would be used to restore the original position of the occlusal plane by applying remaining anatomical landmarks as fixed reference points to facial height.

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