ÖZGÜN ARAŞTIRMA ORIGINAL RESEARCH

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# DEVELOPING A MATHEMATICAL FORMULA TO ESTIMATE OCCLUSAL VERTICAL DIMENSION

## OKLÜZAL DİKEY BOYUTUN TAHMİNİ İÇİN MATEMATİKSEL BİR FORMÜLÜN GELİŞTİRİLMESİ

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## Öz

**Amaç**

Bu çalışmanın amacı antropometrik noktalar arasındaki mesafeyi kullanarak oklüzal dikey boyutu yüksek hassasiyetle hesaplayabilen matematiksel bir formülün elde edilmesidir.

**Gereç ve Yöntem**

Çalışmaya yüz kırk sekiz gönüllü (74 erkek, 74 kadın) dahil edildi. Subnasion-Menton ve yüzdeki diğer on altı mesafeyi ölçmek için dijital bir kumpas kullanıldı. Subnasion-Menton mesafesini tahmin etmek için korelasyon ve regresyon analizi yapıldı. Regresyon analizi ile elde edilen verilerle okluzal dikey boyutu açıklayan matematiksel bir formül geliştirildi. Formülün doğruluğu bireylerden elde edilen veriler üzerinde test edildi.

**Bulgular**

Subnasion-Menton mesafesi Tragus-Tragus, Pupil-Pupil, Inner Canthus-Inner Canthus, Extra Chantus-Extra Chantus, Tragus-Chelion, Pupil-Nose Tip, Pupil-Subnasion , Pupil-Chelion, Tragus-Extra Chantus mesafeleri ile anlamlı korelasyon gösterdi. Toplam R2, 0.5926 idi. Elde edilen formül ile katılımcıların SnMe uzaklıklarının hesaplanmasında % 54 doğruluk oranı gözlendi. Subnasion Menton mesafesi, 1 mm hata payıyla % 61, 2,5 mm hata payıyla % 73 oranında doğru olarak hesaplandı.

**Sonuç**

Yüzdeki antropometrik noktalar arasındaki mesafelerin bir kısmı oklüzal dikey boyutla anlamlı bir ilişkiye sahiptir.. Bu mesafelerin uzunluk değerlerinin istatistiksel analizi ile oluşturulan matematiksel bir formül, oklüzal dikey boyutun hesaplanmasında kullanılabilir.

**Anahtar Kelimeler:** Oklüzal dikey boyut, regresyon formula, tam dişsizlik, antropometri.

## Abstract

**Objective**

The aim of this study is to obtain a mathematical formula that can calculate occlusal vertical dimension with high accuracy, using the distance between the anthropometric points.

**Material and Methods**

One hundred and forty-eight subjects (74 males, 74 females) were included in the study. A digital calliper was used to measure the Subnasion-Menton (SnMe) and the sixteen other distances on the face. The correlation and regression analysis were performed to predict the SnMe distance. A mathematical formula was developed to explain the occlusal vertical dimension with the data obtained by the regression analysis. The accuracy of the formula was tested on data from individuals.

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**Results**
Tragus-Tragus, Pupil-Pupil, Inner Canthus-Inner Canthus, Extra Chantus-Extra Chantus, Tragus-Chelion, Pupil-Nose Tip, Pupil-Subnasion , Pupil-Chelion, Tragus-Extra Chantus Vertical distances had a significant correlation with SnMe. The Total R2 was 0.5926. With this formula, 54% accuracy was observed in calculating participants' SnMe distances. The SnMe distance was estimated to be 61% with an error margin of 1 mm and 73% with an error margin of 2.5 mm.

**Conclusions**
Some of the distances between the anthropometric points on the face have a significant relation with the occlusal vertical dimension. A mathematical formula, to be generated by the statistical analysis of the length values of these distances, can be used to calculate the occlusal vertical dimension.

**Keywords:** Occlusal vertical dimension, regression formula, total edentulism,anthropometrics.

## Introduction

Vertical dimension which occurs when the teeth in maxilla and mandible are in occlusion is called as occlusal vertical dimension (OVD) (1). Re-obtaining of this distance in individuals who lost their OVD due to tooth loss is one of the most important stages of prosthetic treatment. Several methods were reported for the detection of OVD (2). Additionally, none of these methods are sufficient when they are used separately so OVD determination is achieved via a combination of several techniques (2). Anthropometric methods are also used besides several methods in order to determine OVD. In these methods, OVD determination is achieved via numeric data which are obtained by measuring the distances between several parts of the head. Therefore, the possibility to experimentally verify the result is higher when compared to other methods. There is a number of studies which researched the relation between the distances of anthropometric points and OVD (3-7). Some researchers who studied different populations tried to obtain mathematical formulas which can explain OVD for the entire population (7-10). The relation between anthropometric distances can vary according to the races (11). Distances between soft tissue in face and head are measured via different methods in determination of OVD (3-5,12). Due to the differences in the methods used in obtaining the measurements and the anthropometric points taken into consideration, different results were obtained in the studies related to the subject (2). The aim of this study is to obtain a mathematical formula that can calculate OVD with high accuracy using the distance between anthropometric points.

## Material and Methods

The study has been reviewed by independent reviewers and approved by Akdeniz University Faculty of Medicine Clinical Researches Ethics Committee. All individuals had given a written informed consent for taking their photographs and using them and other demographic data. The research was conducted with full accordance with the World Medical Association Declaration of Helsinki.

The study was conducted in the Akdeniz University Faculty of Dentistry. Individuals with Class I occlusion who had no congenital or acquired defect on their faces and had no tooth loss or dental wear that could cause a loss of vertical dimension were included in the study. All the measurements between the anthropometric points were performed on the photographs taken from the individuals. Recommendations in previous studies were followed in the photo-shooting phase (5,13,14). In the study, a 24.2-megapixel camera and a macro lens with focal length between 90 and 120 mm, 1/50 shutter release speed and f/5 lens opening (Nikon D5200, Tokyo, Japan) were used. White light source (100485 HR Soft Box, Profoto, Italia) and white opaque background were used for lighting. In order to be a reference to the face measurements to be made in the computer, two standard milimetric rulers are provided in each photograph frame vertically and horizontally (Figure 1). The position of the rulers is at the level of the forehead of the individuals in the sagittal way, and the frontal positions are shown in figure 1 (Figure 1). Photos were taken to provide Frankfurt horizontal planes were parallel to the ground and midsagittal planes were vertical. Photographs were transferred to a computer and each was subjected to distance measurements in a photo editing software (Adobe Photoshop CS6, Adobe Systems Inc., San Jose, CA). The distances which were measured were Subnasion – Menton (SnMe), Tragus- Tragus (TT), Chelion – Chelion (ChCh), Alare – Alare (AlAl), Pupil – Pupil (PP), Inner Canthus – Inner Canthus (ICIC), Extra Chantus - Extra Chantus (ECEC), Tragus- Pupil (TrP), Tragus – Glabella (TrG), Tragus – Subnasion (TrSn), Tragus – Chelion (TrCh), Glabella – Subnasion (GSn), Pupil – Nose Tip (PTN), Pupil – Subnasion (PSn), Pupil – Chelion (P – Ch), Tragus – Extra Chantus Horizontal (TrECH) and Tragus – Extra Chantus Vertical (TrECV) distances (Table 1). SnMe distance which was selected to represent OVD was accepted

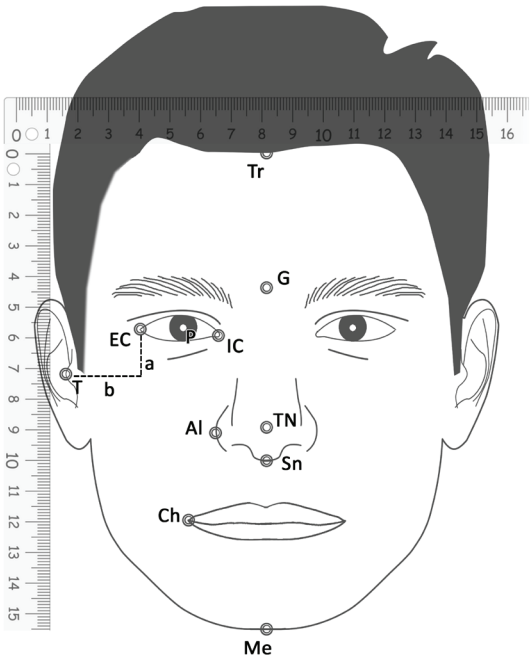


**Figure 1:** Measured anthropometric points in this study. ("a" represents the vertical distance between Tr and ECV and "b" represents the horizontal distance)

as independent variable whilst all the other distances were accepted as dependent variables. Data was analyzed via SAS statistical program. Correlation coefficient (r) between all the dependent and independent variables were obtained. Multivariate regression analysis was applied to the variables that were found to be significant with the correlation analysis in order to examine the relationship between dependent and independent variables. The method can be given with the following formula in general:

$$yi = b0 + b1x1i + b2x2i + \ldots + bpxpi + ei$$
$$i = (1, 2, \ldots, n)$$

yi is dependent variable, *x1i, x2i, …, xp* are independent variables and *b0, b1, b2, bp* are regression coefficients. The obtained formula was tested on the data of the individuals and the degree of reliability and error margin of the formula were examined.

## Results

The average and standard deviation of the age of the individuals involved in the study were found to be 20.01 ± 1.44. Descriptive statistics of the measured variables (average, standard deviation, minimum and maximum) are shown in Table 1. Correlations between dependent variable SnMe and independent variables are shown in Table 2. Upon examining Table 2, it was

**Table 1** Descriptive statistics of dependent and independent variables.

| | n | Mean | Sd. | Min. | Max |
|---|---|---|---|---|---|
| **SnMe** | 148 | 66.592 | 5.442 | 54.00 | 78.5 |
| **TT** | 148 | 146.969 | 7.63 | 132.00 | 169.00 |
| **ChCh** | 148 | 50.324 | 4.063 | 42.5 | 59.5 |
| **AlAl** | 148 | 37.193 | 2.941 | 30.5 | 45.00 |
| **PP** | 148 | 64.237 | 3.607 | 56.00 | 73.5 |
| **IC** | 148 | 32.898 | 3.114 | 25.00 | 41.5 |
| **ECEC** | 148 | 92.864 | 4.328 | 83.00 | 104.5 |
| **TrG** | 148 | 59.704 | 5.93 | 45.00 | 79.00 |
| **TrP** | 148 | 73.408 | 6.348 | 54.00 | 94.00 |
| **TrCh** | 148 | 142.68 | 8.51 | 117.00 | 167.00 |
| **TrSn** | 148 | 120.929 | 7.832 | 100.00 | 140.5 |
| **GSn** | 148 | 61.224 | 4.129 | 50.00 | 73.00 |
| **PTN** | 148 | 37.347 | 4.371 | 27.5 | 57.00 |
| **PSn** | 148 | 47.694 | 3.731 | 38.5 | 61.5 |
| **PCh** | 148 | 69.707 | 4.57 | 57.00 | 90.00 |
| **TrECH** | 148 | 24.143 | 5.808 | 6.00 | 41.00 |
| **TrECV** | 148 | 26.69 | 4.187 | 16.00 | 37.00 |

**Table 2** Correlations between independent variables with dependent variable SnMe.

| | SnMe |
|---|---|
| **TT** | 0.58898** |
| **ChCh** | 0.18300 |
| **AlAl** | 0.19220 |
| **PP** | 0.35485** |
| **ICIC** | 0.24200* |
| **ECEC** | 0.27201* |
| **TrP** | -0.03167 |
| **TrG** | 0.10528 |
| **TrSn** | 0.02285 |
| **TrCh** | 0.23646* |
| **GSn** | -0.10785 |
| **PTN** | -0.26365* |
| **PSn** | 0.51646** |
| **PCh** | 0.44594** |
| **TrECH** | 0.15351 |
| **TrECV** | 0.42033** |

(*p<0.05, **p<0.01).

**Table 3** Regression analysis results used to select independent variables that best describe the dependent variable SnMe.

| | Parameter Estimation | Sd. | Partial $R^2$ |
|---|---|---|---|
| **Intercept** | -6.28857 | 8.13830 | |
| **TT** | 0.50896 | 0.08526 | 0.3469 |
| **PP** | 0.51602 | 0.17709 | 0.0070 |
| **ICIC** | -0.27914 | 0.14044 | 0.0113 |
| **ECEC** | -0.21962 | 0.12941 | 0.0086 |
| **TrCh** | -0.18705 | 0.09784 | 0.0148 |
| **PTN** | -0.22814 | 0.14484 | 0.0068 |
| **PSn** | -0.35808 | 0.17907 | 0.0960 |
| **PCh** | 0.63841 | 0.09536 | 0.0873 |
| **TrECV** | 0.09057 | 0.05901 | 0.0139 |
| **$R^2$ Total** | 0.5926 | | |

observed that TT, PP, ICIC, ECEC, TrCh, PTN, PSn, PCh, TrECV distances had a significant correlation with SnMe. The regression analysis results that were carried out with independent variables which explain dependent variable SnMe the best are shown in Table 3. According to the Table 3 total of R2 is 0.5926 and when the data were placed in the above formula the formula which describes SnMe the best is as follows:

SnMe= -6.28857 + 0.50896 x TT + 0.51602 x PP - 0.27914 x ICIC - 0.21962 x ECEC - 0.18705

* TrCh - 0.22814 * PTN - 0.35808 x PSn + 0.63841 x PCh + 0.09057 x TrECV

When the formula is applied to the participants' data, 54% accuracy was observed in calculating participants' SnMe distances. Participants' SnMe distance was estimated 61% with an error margin of 1 mm and 73% with an error margin of 2.5 mm.

## Discussion

In cases where dental treatment involves reorganization of the OVD, prosthetic treatment should re-establish the patient's natural OVD. In this case, the dentist will reestablish the patient's correct OVD by utilizing the patient's existing data. In the literature, several methods were reported for the detection of OVD (2). Some of these methods are based on restoration of proportional harmony of the facial features. In this study, the relationship between the distances determined on the face and the distance between the SnMe representing the OVD was investigated and this relationship was explained with a mathematical formula. Parameters which are found to have significant relations with SnMe distance are gathered via a formula that will be used to calculate SnMe. In the literature, there are several studies in which the relation between the distances of certain facial points and OVD were analysed (2-4,6). However; most of these studies failed to develop a detailed formula to estimate OVD. In a previous study, Domitti and Consani (8) developed a formula to calculate Subnasion - Gnathion distance by using Nasion and Subnasion and byzygomatic distances. In the study, measurements were taken directly from the faces of the individuals and no sufficient information was given about the validity of the formula in the study results. In a study which was carried out in 1979 based on the same measurement points, Darvell and Spralley (9) reported that the obtained formula did not provide clinically accepted results. Delić et al. (7,10) developed two different formulas by using Euron-Euron distance in one formula and Zy - Zy distance in the other in order to calculate SnGn distance. In this study, measurements were taken directly from the individual by means of a caliper and no sufficient information was given about the validity of the formula.

Contrary to many studies, in the present study all measurements were taken from the standardized photos. This method enables more measurements from the individuals in an easier and more reliable way (5). Relation of 16 different parameters with SnMe distance were analyzed in the present study. The parameter count of the study is highly more than similar previous studies. Existence of more parameters is thought to help a stronger mathematical formula in predicting OVD. It was observed that TT, PP, ICIC, ECEC, TrCh, PTN, PSn, PCh, TrECV distances had positive or negative correlation with SnMe. The above formula which was obtained via regression analysis of the measurements enabled accurate calculation of SnMe distances in more than half of the participants of the study. When SnMe values which were obtained via the formula were compared with participants' real SnMe values and the correct estimation are added to the results having 1 mm error margin, the formula was observed to have an accuracy rate of 61%. The rate was found as 73% in 2.5 error margin. The rates indicate that the formula which was obtained in the present study can be used as a supportive method in estimating vertical dimension. In addition to that, factors such as numerosity of the parameters to be involved in the calculation when the formula is applied and the necessity for precision of the measurements are obstacles for the routine implementation of the method.

There have been several technological developments in dentistry in the last 10 years. Nowadays, technologies such as obtaining dental impressions via digital methods and production of restoration with computer aided are involved in routine clinical use. In recent years, various steps have been taken regarding the production of complete dentures by digital methods (16,17). There are studies on the application of digital and virtual methods in the use of the face bows, which determines the position of the jaws in space (18,19). Determination of OVD accurately is of great significance in terms of carrying out a successful prosthetic treatment. The problems resulting from high or low OVD is reported in the literature in detail (20-23). From this point of view, determination of OVD via digital methods is thought to be a subject which is worth researching. In the studies which use the face arch are carried out virtually, participants' records are taken via transferring several anthropometric points in facial and dental arches to virtual platform (18,24). This shows that the correlations or mathematical formulas obtained by comparing the OVD with the distance between the anthropometric points can be processed by software that can detect anthropometric points.

In this study, a new mathematical formula which enables estimation of OVD by using facial measurement is developed. The formulas which will be used to estimate OVD provide a base for future digital studies. New formulas that calculate OVD with higher accuracy rates should be developed and software and devices that perform OVD calculations based on these formulas should be produced.

## Conclusion

Some of the distances between anthropometric points on face have a significant relation with OVD. A mathematical formula to be generated by the statistical analysis of the length values of these distances can be used to calculate the OVD.

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