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Evaluation of Various Facial Measurements as an Adjunct in Determining Vertical Dimension at Occlusion in Dentate Individuals—A Cross-Sectional Study

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Abstract: Background: For optimal clinical outcomes in full mouth rehabilitations, it is vital to determine the optimal jaw relations and confirm the appropriate vertical dimension of occlusion (VDO). The current study aims to evaluate various facial measurements as an adjunct in determining VDO in dentate individuals. **Methods**: A total of one hundred and twenty subjects, sixty males and sixty females, of the age group 19-30 were selected for the study. VDO (chin–nose distance) and other facial measurements like the glabella to subnasion (G-S) distance, both right and left pupil to rima oris (P-R) distance, both right and left corner of mouth to outer canthus of eye (M-E) distance, and both right and left ear to eye (E-e) distance were measured using a Vernier caliper. **Results**: The mean ± standard deviation of the C-N distance, G-S distance, right P-R distance, right M-E distance, left M-E distance, right E-e distance, and left E-e distance were 67.70 mm ± 3.22 mm, 60.29 mm ± 3.67 mm, 65.99 mm ± 3.72 mm, 66.00 mm ± 3.91 mm, 69.51 mm ± 3.71 mm, 69.48 mm ± 3.68 mm, 69.59 mm ± 3.98 mm, and 69.51 mm ± 3.95 mm, respectively. Pearson's correlation coefficient between the C-N distance and M-E distance was found to be 0.739 (right), 0.730 (left); that between the C-N distance and E-e distance was found to be 0.738 (right), 0.732 (left); that between the C-N distance and P-R distance was found to be 0.660(right), 0.670(left); and that between the C-N distance and G-s distance was found to be 0.417. **Conclusions**: The present study reported a high positive correlation between the chin to nose distance and the distance between both the right and left lateral corner of the mouth to the outer canthus of the eye, and the distance between both the right and left ear to the eye. Hence, these measurements can be used as an adjunct for establishing VDO in the edentulous patient.

Keywords: vertical dimension of occlusion; facial measurements; jaw relations; corner of mouth; outer canthus of eye

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1. Introduction

Complete dentures are a standard treatment option for patients with missing natural teeth. The procedure helps patients regain their esthetics and functional abilities by replacing missing teeth and associated structures [1]. For optimal clinical outcomes in full mouth rehabilitations (complete dentures, implant-supported prosthesis, and collapsed bite due to attrition), it is vital to determine the optimal jaw relations and confirm the appropriate vertical dimension of occlusion (VDO). The current study aims to evaluate various facial measurements as an adjunct in determining VDO in dentate individuals [2].

The Glossary of Prosthodontic Terms defines VDO as the distance between two selected anatomic or marked points (usually one on the tip of the nose and the other on the chin) when in maximal intercuspal position [3].

The establishment of VDO is a crucial factor while rehabilitating completely or partially edentulous patients. Over time, these patients can adapt to decreased vertical dimension (VD) due to posterior tooth wear and bone resorption. Alteration in the rest position may complicate the restoration of vertical dimension [4]. However, restoring proper VD is essential to avoid undesirable functional and esthetic consequences and prevent treatment failure [5].

Multiple theories were postulated on techniques to determine VD. Due to heterogeneity between clinic patients, a single concept cannot be followed to determine VDO [6]. Various methods proposed to determine VDO include using pre-extraction records as reference [7], electromyography [8], cephalometric records [9], facial measurements, esthetics, phonetics, and physiological rest position [10]. The ease of recording and instrument handling, repeatability, precision, and time required for recording are some factors that help determine the method of recording VDO [11].

Multiple techniques proposed for determining VDO have their advantages and shortcomings [12,13]. Studies have revealed that the position of the head, airway position, and patient's emotions affect the physiological rest position. Therefore, it is not a reliable reference point [13]. Swallowing and occlusal biting pressure techniques were employed to determine VDO, but their use is also condemned [7,14–16]. Phonetics is commonly used to determine VDO [17]. The cephalometric measurements technique is more empirical when compared to other techniques, but the measurements are two-dimensional and static. Studies have reported associations between facial soft tissue landmarks and VDO. These landmarks are reported to be reliable, easy to access, and remain more or less unaffected during the course of life [18].

Ivy used Leonardo Da Vinci's concepts of facial drawings in complete denture fabrication. He divided the face into four equivalent proportions and utilized these in complete denture fabrication [19]. Goodfriend modified Ivy's parameters and proposed that the measurements between the pupil and rima oris are the same as those between the chin and nose [20]. Willis gauge was created by Willis and was based on the same principles as Goodfried [21]. Later, Fenn et al. suggested that the distance between the eye's outer canthus and the mouth's angle can be used to determine VDO [22]. McGee associated the distance between three more landmarks (the center of the pupil to a lateral line from lip median, glabella to subnasion, and between mouth angles) with VDO [23].

Although the literature is inconsistent, facial reference points remain a popular method in clinical practice to measure VD in edentulous patients. Their ease of use, non-invasive nature, and low cost make both caliper and Willis gauge techniques popular in research [24].

The current study evaluated several facial measurements as an adjunct in establishing VDO in dentate individuals. This was attained by taking the average distance of various facial landmarks in dentate population: the glabella to subnasion distance, right and left pupil to rima oris distance, right and left lateral corner of mouth to outer canthus of eye distance, and right and left ear to eye distance. These recordings were compared and associated with the distance between the nose tip and the most prominent point on the chin, measured using Niswonger's method [25].

2. Materials and Methods

The current cross-sectional analytical study was conducted in the Department of Prosthodontics and Maxillofacial Prosthesis, UCMS College of Dental Surgery. The study was approved by the Institutional Review Committee, Universal College of Medical Sciences, Bhairahawa, Nepal (UCMS/IRC/042/18). The study was conducted from February 2019 to January 2020. The inclusion criteria were subjects of age group 19–30 years, no attrition of dentition, Angle's Class I molar relation, subjects with all natural teeth, among which third molar is inconsiderate, no facial asymmetry, no trauma to soft and hard tissues, no history of orthodontic and prosthodontic treatment, and no gross malocclusion. Exclusion criteria included the absence of teeth, facial asymmetry, and gross malocclusion. The convenience sampling technique was used to select the sample. A total of 120 (60 males and 60 females) samples were selected in this research. All students from the first year to the internship were examined, and those who met the inclusion criteria were selected for the study. Only a limited number of students were included because the total number of samples which fulfilled all criteria was limited. Informed consent was obtained from all subjects prior to commencement of the study. The subjects were divided into two groups according to gender, males (60) and females (60).

Facial measurements were recorded by asking the participants to sit straight while the head was not supported. Participants were directed to occlude in maximum intercuspation and keep their lips relaxed. Niswonger's technique was used for VD measurements. The two selected points were the nose tip (on the non-movable member) and the most prominent point on the chin (on the movable member). The other facial landmarks were palpated and the points were marked on the pieces of adhesive tape affixed on the subjects' face with the help of a cello permaline permanent marker. The points marked were the following:

1. Glabella (G): The point of greatest prominence between the two eyebrows; 2. Subnasion (S): The base of the nose; 3. The tip of the nose (N); 4. The most prominent point of the chin (C); 5. The center of the pupil (P); 6. Rima oris (R): The line between the upper and lower lips; 7. The lateral border of the bony orbit (outer canthus of the eye) (E); and 8. The most anterior point of the external auditory meatus (e).

2.1. Facial Measurements

The vertical dimension at occlusion (chin to nose distance or C-N) was measured between the most prominent part of the chin and nose with the help of a digital Vernier caliper (Figure 1).

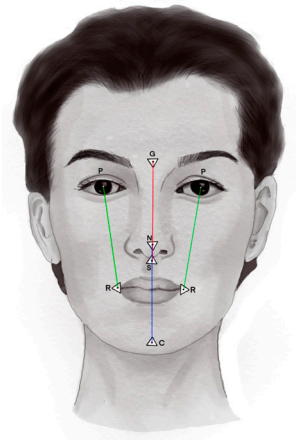

Figure 1. Measurement of chin to nose distance (C-N), glabella to subnasion distance (G-S), and pupil to rima oris distance (P-R).

A digital Vernier caliper was used to record other facial measurements:

1. The glabella to subnasion distance was measured from the glabella to the base of the nose [G-S] (Figure 1).

2. The right and left pupil to rima oris distance was measured from the center of the pupil to rima oris [P-R] (Figure 1).
3. The right and left lateral corner of the mouth to outer canthus of the eye distance was measured from the lateral corner of mouth to the lateral border of the bony orbit [M-E] (Figure 2).
4. The right and left ear to eye distance was measured from the most anterior point of the external auditory meatus to the lateral border of the bony orbit [E-e] (Figure 2).

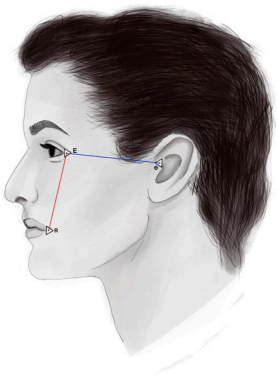

Figure 2. Measurement of lateral corner of mouth to outer canthus of eye distance (R-E), and ear to eye distance (E-e).

2.2. Statistical Analysis

All the statistical analyses were performed using the Statistical Package for Social Science (SPSS), version 20 (IBM SPSS Statistics for Windows, IBM Corp., Armonk, NY, USA). Intra-observer reliability was assessed using Cronbach's Alpha. Descriptive statistics including mean, standard deviation, range, and minimum and maximum values were calculated. A Pearson correlation coefficient test was used to analyze the correlation between the chin to nose distance and glabella to subnasion distance, the correlation between the chin to nose distance and both right and left pupil to rima oris distance, the correlation between the chin to nose distance and both right and left lateral corner of mouth to outer canthus of eye distance, and the correlation between the chin to nose distance and both right and left ear to eye distance. Significance for all statistical tests was predetermined at $p < 0.01$.

3. Results

The reliability of variables was tested using Cronbach's Alpha method and it was seen that Cronbach's Alpha values for all parameters were greater than 0.8, which shows that the data are reliable (Table 1).

Table 1. Intra-observer reliability. Cronbach's Alpha for different variables.

Variables	Cronbach's Alpha
C-N Distance	0.96
G-S Distance	0.94
Right P-R Distance	0.93
Left P-R Distance	0.92
Right M-E Distance	0.92
Left M-E Distance	0.91
Right E-e Distance	0.96
Left E-e Distance	0.96

The mean, standard deviation, range, minimum value, and maximum value of each parameter were computed for each participant. The Pearson correlation coefficient test (PCT) was used to analyze the correlation between vertical dimension at occlusion (C-N distance) and other facial measurements. The present study included a total of 120 samples, 60 males and 60 females. A comparative graph of mean (in mm) of different parameters according to gender is depicted in Figure 3. Table 2 shows the mean values, standard deviation, range, minimum values, and maximum values of different measurements of the overall sample and the female and male samples.

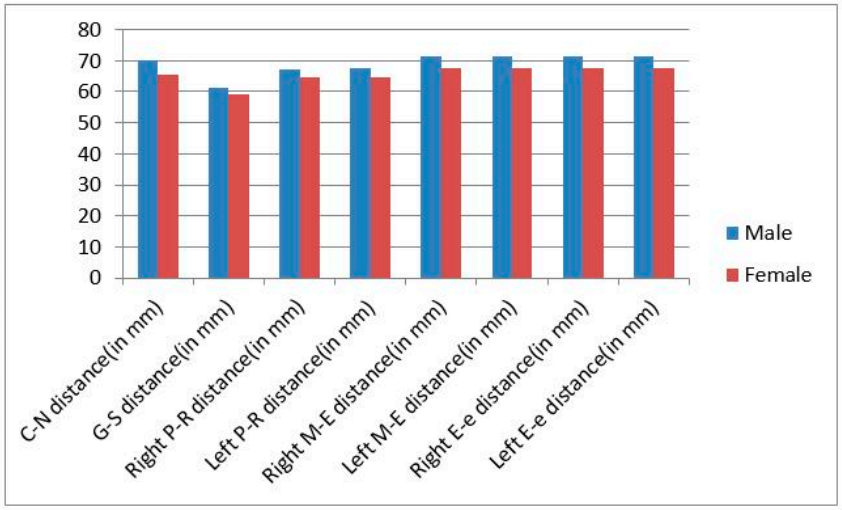

Figure 3. Comparative graph of mean (in mm) of different parameters according to sex.

Table 2. Mean ± standard deviation of the study variables.

	C-N Distance (mm)	G-S Distance (mm)	Right P-R Distance (mm)	Left P-R Distance (mm)	Right M-E Distance (mm)	Left M-E Distance (mm)	Right E-e Distance (mm)	Left E-e Distance (mm)
Female Group (n = 60)								
Mean ± SD	65.46 ± 1.89	59.34 ± 3.80	64.66 ± 3.63	64.57 ± 3.65	67.70 ± 3.23	67.71 ± 3.30	67.64 ± 3.50	67.59 ± 3.49
Range	8.52	20.43	20.00	20.00	17.00	17.00	17.53	17.53
Minimum	60.33	49.05	54.64	54.64	59.84	59.84	59.19	59.19
Maximum	68.85	69.48	74.64	74.64	76.84	76.84	76.72	76.72
Male Group (n = 60)								
Mean ± SD	69.94 ± 2.73	61.24 ± 3.30	67.31 ± 3.35	67.42 ± 3.66	71.31 ± 3.27	71.25 ± 3.17	71.54 ± 3.46	71.43 ± 3.43
Range	15.78	14.55	18.48	18.48	15.05	15.87	15.26	15.27
Minimum	62.15	52.90	56.85	56.85	62.17	62.17	63.72	63.71
Maximum	77.93	67.45	75.33	75.33	77.22	78.04	78.98	78.98
Overall (n = 120)								
Mean ± SD	67.70 ± 3.24	60.29 ± 3.67	65.99 ± 3.72	66.00 ± 3.91	69.51 ± 3.71	69.48 ± 3.68	69.59 ± 3.98	69.51 ± 3.95
Range	17.60	20.43	20.69	20.69	17.38	18.20	19.79	19.79
Minimum	60.33	49.05	54.64	54.64	59.84	59.84	59.19	59.19
Maximum	77.93	69.48	75.33	75.33	77.22	78.04	78.98	78.98

The PCT revealed a weak positive correlation (r = 0.473) between C-N distance and G-S distance. It was statistically significant (Table 3 and Figure 4). The PCT revealed a moderate positive correlation between C-N distance and both right (r = 0.664) and left (r = 0.674) P-R distance. It was statistically significant (Table 3 and Figures 5 and 6).

Table 3. Correlation between various variables (n = 120).

Variables	Value of Significance	Correlation Coefficient (r)
C-N distance–G-S distance	$p < 0.01$	0.429 **
C-N distance–right P-R distance	$p < 0.01$	0.664 **
C-N distance–left P-R distance	$p < 0.01$	0.674 **
C-N distance–right ME distance	$p < 0.01$	0.759 **
C-N distance–left M-E distance	$p < 0.01$	0.751 **
C-N distance–right E-e distance	$p < 0.01$	0.746 **
C-N distance–left E-e distance	$p < 0.01$	0.740 **

** Correlation is significant at the 0.01 level (two-tailed).

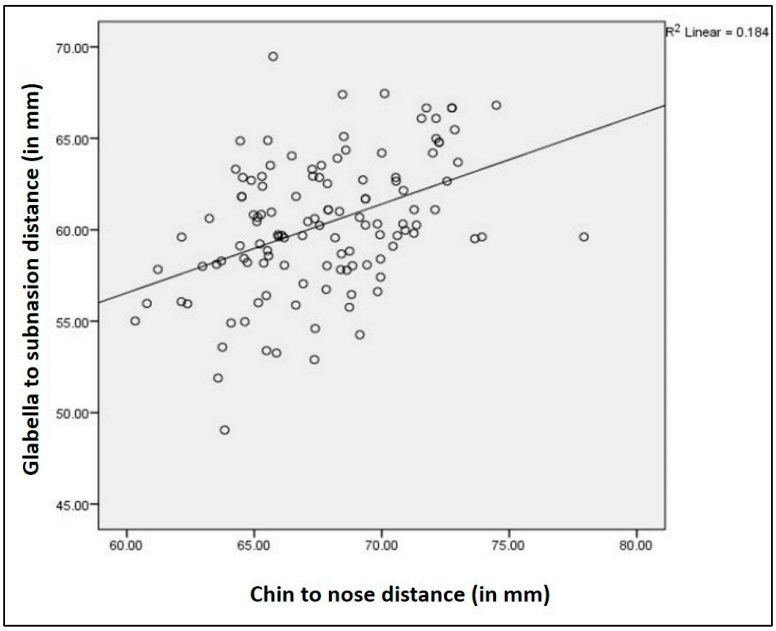

Figure 4. Linear relationship between C-N distance and G-S distance.

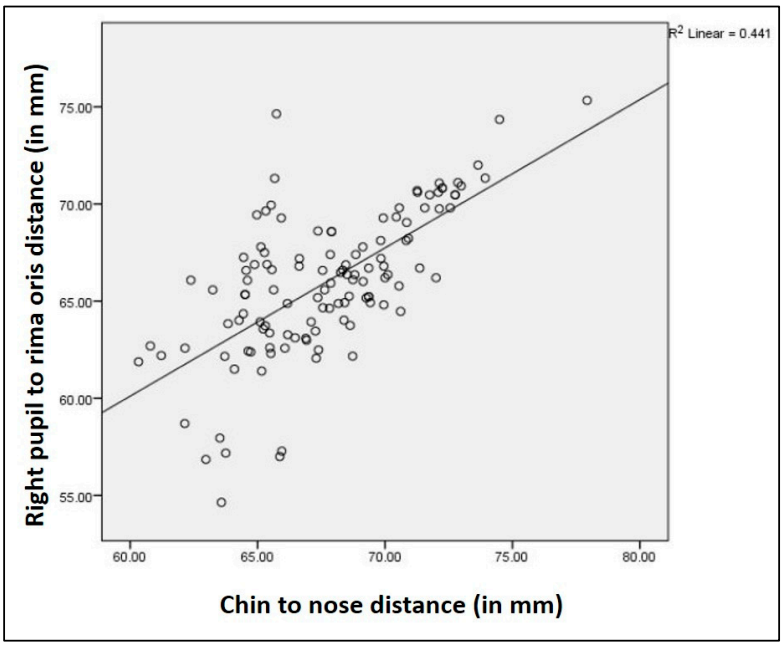

Figure 5. Linear relationship between C-N distance and Right P-R distance.

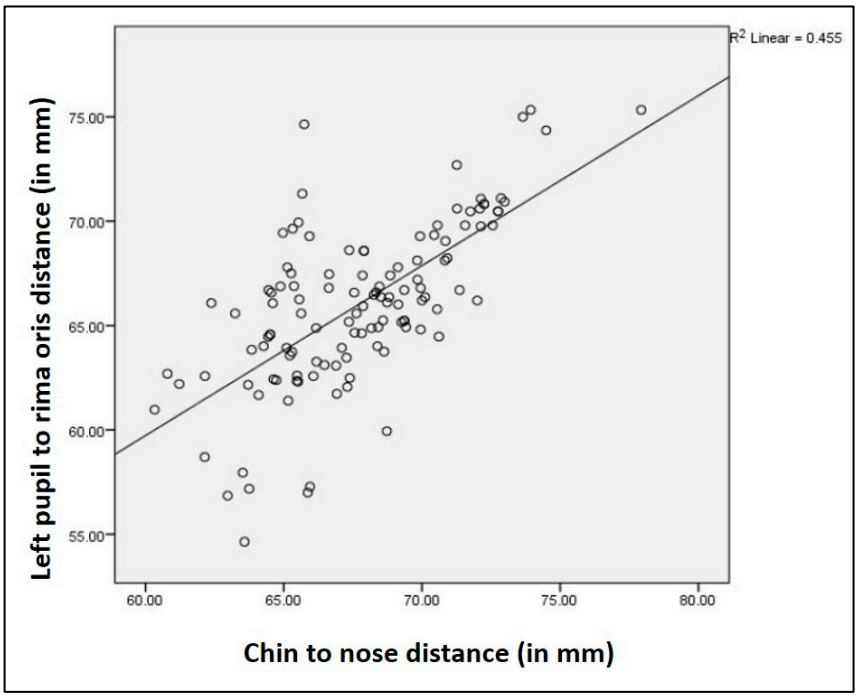

Figure 6. Linear relationship between C-N distance and Left P-R distance.

The PCT revealed a high positive correlation between C-N distance and both right (r = 0.759) and left (r = 0.751) M-E distance. It was statistically significant (Table 3 and Figures 7 and 8). The PCT revealed a high positive correlation between C-N distance and both right (r = 0.746) and left (r = 0.740) E-e distance. It was statistically significant (Table 3 and Figures 9 and 10). Table 2 shows the sample size, mean, standard deviation, range, minimum value, and maximum value of each parameter of the study.

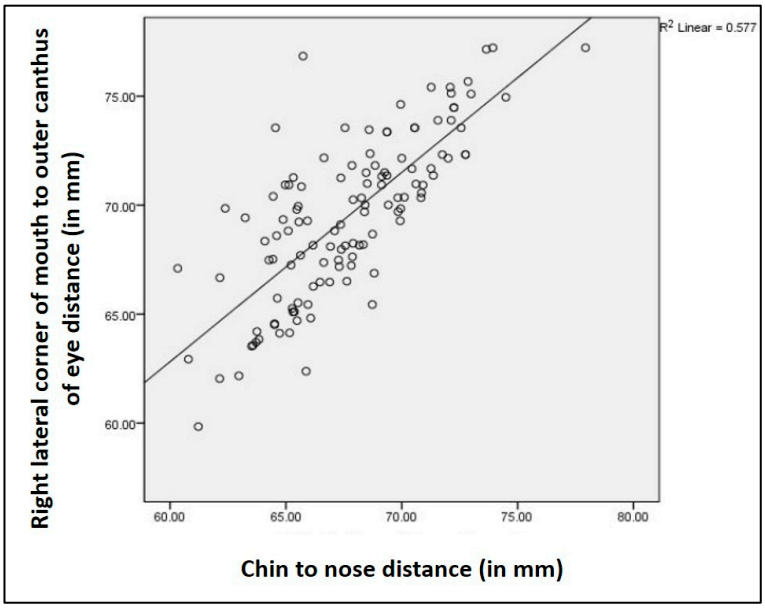

Figure 7. Linear relationship between C-N distance and Right M-E distance.

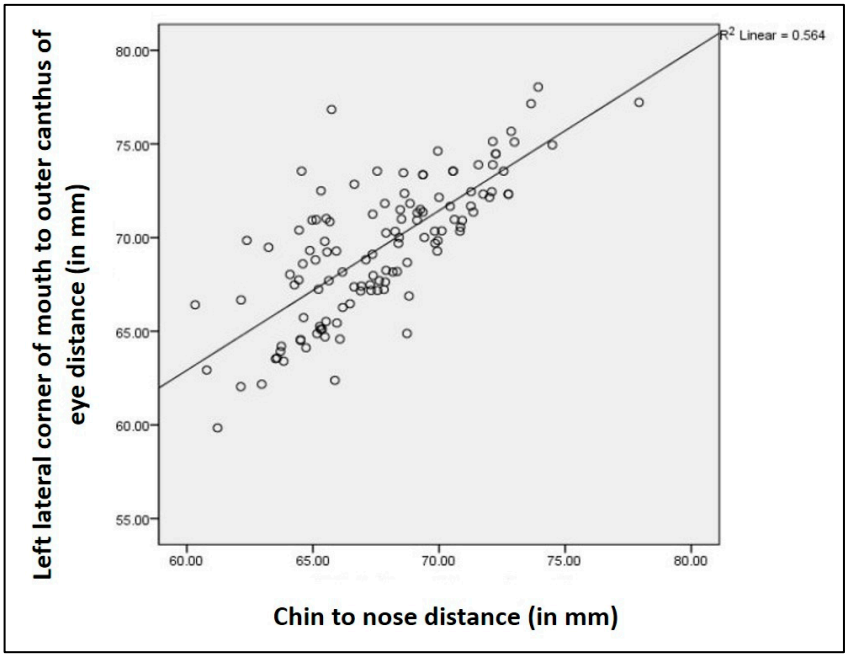

Figure 8. Linear relationship between C-N distance and Left M-E distance.

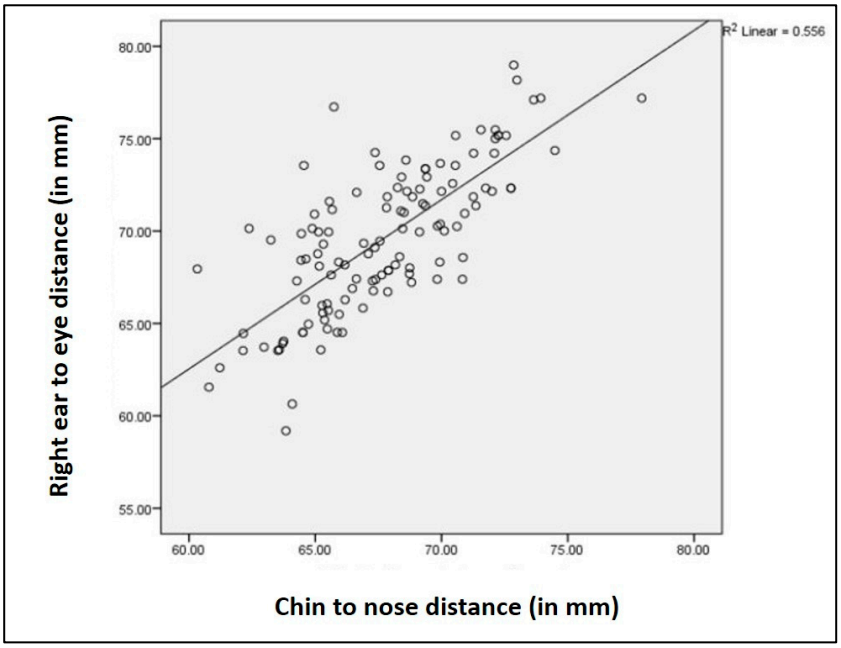

Figure 9. Linear relationship between C-N distance and Right E–e distance.

The results revealed the mean values of different parameters in male and female samples. The mean value of the C-N distance for males is 69.94 mm and for females 65.46 mm. The mean value of the G-S distance for males is 61.24 mm and for females it is 59.34 mm. The mean value of the right P-R distance for male is 67.31 mm and for females it is 64.66 mm. The mean value of the left P-R distance for males is 67.42 mm and for females it is 64.57 mm. The mean value of the right M-E distance for males is 71.31 mm and for females it is 67.70 mm. The mean value of the left M-E distance for males is 71.25 mm and for females it is 67.67 mm. The mean value of the right E-e distance for males is 71.54 mm and for females it is 67.64 mm. The mean value of the left E-e distance for males is 71.43 mm and for females it is 67.59 mm.

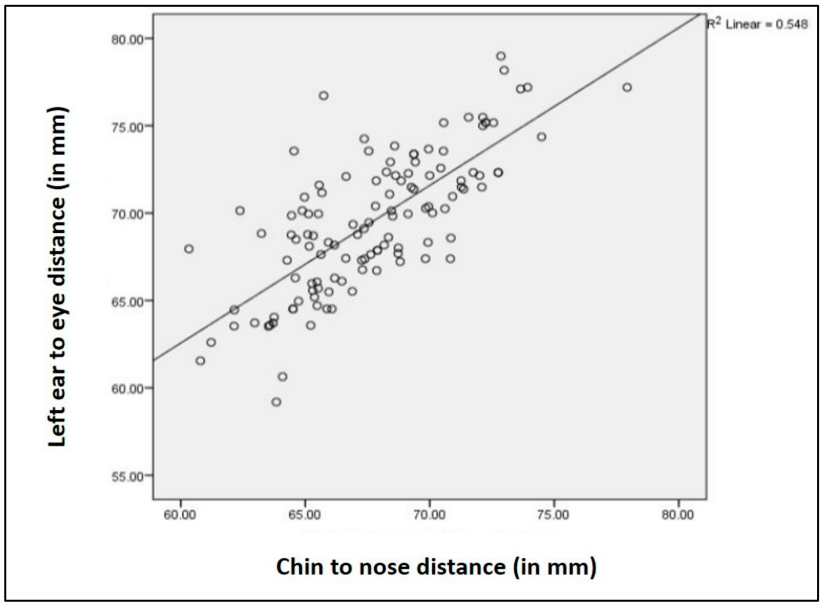

Figure 10. Linear relationship between C-N distance and Left E-e distance.

4. Discussion

For complete denture fabrication, it is important to achieve VD accurately. There are different ways to measure the vertical dimension at occlusion in patients with and without teeth. The evaluation of VDO heavily depends on the clinician's expertise and judgment as there is no single precise and universally acknowledged method to determine VDO in edentulous patients [26].

Methods to determine VDO can be broadly classified into two types: (a) physiologic methods, which assess physiologic rest position, esthetics, phonetics, and patient relaxation, and (b) mechanical methods, which include evaluating facial dimensions, pre-extraction records, and cephalometric and electromyographic analysis. Physiologic methods are subjective, whereas mechanical methods are objective [19]. The physiologic methods are scientifically nonspecific, whereas some mechanical methods like electromyographic analysis and bite fore evaluations are impractical to use in routine clinical practice as they require complex instruments. Thus, using facial measurements to determine VDO can be a more practical method. This method consumes less time, is simple, and does not require complex, expensive instruments [27]. In addition, the facial landmarks remain unaltered throughout life and thus can be a reliable guide in determining VD in completely edentulous patients. Greets et al. reported that the compressibility of skin over the selected anatomical landmarks can incur errors while measuring VDO using facial measurements [28].

Ivy was first to propose the use of facial measurements in the dental field. He advocated that the face could be divided into four equal proportions, starting from the top of the head to the front roots of the hair, then from the hairline to the root of the nose (between the eyes), followed by the distance from the root of the nose to the bottom of the nose, and, finally, from the bottom of the nose to the bottom of chin [19]. It was considered that these correlations could be simplified into basic ratios. A study by Chou et al., in which associations between the ear–eye distance and VDO were evaluated, reported that these correlations are not basic ratios but are in fact complex equations [29]. McGee conducted a study on the relationship between three facial measurements—the distance from the center of the pupil of the eye to a line projected laterally from the median line of the lips, the distance from the glabella to the subnasion, and the distance between the angles of the mouth with the lips in repose. He reported that in 95% of scenarios, at least two of the three measurements were aligned with VD [23]. Tina-Olaivar et al. reported a 3 cm difference between the measurements of the upper and lower halves of the face, which contradicts the Willis technique [30].

In the current study, the focus was on determining the relation between different facial measurements like the chin–nose distance, the glabella–subnasion distance, the pupil–rima oris distance, the distance between the lateral corner of the mouth and the outer canthus of the eye, and the ear–eye distance [31].

Students aged nineteen to thirty years were included in the current study. This was based on the results of the study by Ricketts et al. [32], who concluded that lower facial height in adults stays constant with age. In the present study, each subject was asked to sit straight with head unsupported for the physiologic rest position; in this pose, the condyles are in a neutral, unstrained position in the glenoid fossae. Every participant was asked to relax the lips and was instructed to occlude in maximum intercuspation. For measuring VDO, facial landmarks suggested by Niswonger were used (the nose tip and the most prominent point on the chin) [25]. The recording of facial measurements was performed bilaterally at VDO to determine any correlation. The current study followed Thompson's facial symmetry concepts, which stated that no face is precisely symmetrical and that normal asymmetry is not very obvious.

The current study employed a digital Vernier caliper for the measurement of VDO and other facial landmarks similar to those used in previous studies by Miran [33], Nazir et al. [34], and Ladda et al. [12]. Geerts et al. stated that the caliper method is more consistent than the Willis gauge method for the measurement of VDO. The cost of the caliper is less. They reported that dental students were able to master the caliper technique quickly, and their VDO measurements were more accurate when compared to using the more familiar Willis gauge technique [28].

In the present study, the average of VDO (chin to nose distance) was found to be 67.67 ± 3.25 mm in the total population, 69.94 ± 2.73 mm in males, and 65.40 ± 1.86 mm in females, which was within the same range as in the studies of McGee [23], Nagpal et al. [1], and Kassab et al. [35]. McGee proposed an average value of VDO between 65 and 70 mm in the total population [23]. Nagpal et al. proposed an average value of VDO of 67.25 ± 6.5 mm in dentate subjects [1]. In the study by Kassab et al., the vertical dimension at occlusion in 75 students was 66.74 ± 6.468 mm. VDO in males was 68.25 ± 6.134 mm and in females it was 63.99 ± 6.254 mm [35]. However, in the studies carried out by Basnet et al. [18] and Ladda et al. [12], the mean values of the vertical dimension at occlusion were reported to be lower than those in this study.

The mean value of other facial measurements like the glabella to subnasion distance was found to be 60.29 ± 3.67 mm in the total population, 61.24 ± 3.30 mm in males, and 59.34 ± 3.80 mm in females, which was within the same range as in the study of Nagpal et al. [1]. The mean value of the right pupil to rima oris distance was found to be 65.99 ± 3.72 mm in the total population, 67.31 ± 3.35 mm in males, and 64.66 ± 3.63 mm in females, and the mean value of the left pupil to rima oris distance was 66.00 ± 3.91 mm in the total population, 67.42 ± 3.66 mm in males, and 64.57 ± 3.65 mm in females, which was within the same range as in the study of Basnet et al. [18]. But in the previous study by Nagpal et al. in Indian dentulous and edentulous subjects, it was found to be greater than this study [1]. The mean value of the right lateral corner of mouth to outer canthus of eye distance was found to be 69.51 ± 3.71 mm in the total population, 71.31 ± 3.27 mm in males, and 67.70 ± 3.23 mm in females, and the mean value of the left lateral corner of mouth to outer canthus of eye distance was found to be 69.48 ± 3.68 mm in the total population, 71.25 ± 3.17 mm in males, and 67.71 ± 3.30 mm in females, which was within the same range as in the studies of Nagpal et al. [1] and Alhaj et al. [5].

The mean value of the right ear to eye distance was found to be 69.59 ± 3.98 mm in the total population, 71.54 ± 3.46 mm in males, and 67.64 ± 3.50 mm in females, and the mean value of the left ear to eye distance was found to be 69.51 ± 3.95 mm in the total population, 71.43 ± 3.43 mm in males, and 67.59 ± 3.49 mm in females, which was within the same range as in the studies of Nagpal et al. [1] and Basnet et al. [18]. Gender-based differences in the mean values of VDO and other facial measurements were found in this study where values in females were significantly lower than those in males. This was in

agreement with similar studies conducted by Kassab et al. [35] and Ladda et al. [12]. The variation in the mean values may be because of differences in growth and development based on gender-associated characteristics [36]. Also, the differences may be related to less prognathic and shallower mandibular angles in females when compared to males [37].

The Pearson correlation test was employed to determine any correlation between the chin–nose distance and the distance between other tested facial landmarks. In the present study, a positive correlation was found between these landmarks. Thus, it can be stated that if someone has a large face, it is likely that their vertical dimension is also large and vice versa. The present study showed a high positive correlation of the chin to nose distance with both right and left lateral corner of mouth to outer canthus of eye distance (right r = 0.739, left r = 0.730), which was statistically significant (p value <0.01), as shown in Table 3. The result is supportive to the studies carried out by Fenn et al. [22], Bajunaid et al. [27], and Alhaj et al. [5].

The present study showed a high positive correlation of the chin to nose distance with both right and left ear to eye distance (right r = 0.738, left r = 0.732), which was statistically significant (p value < 0.01), as shown in Table 3. The result is supportive to the studies carried out by Chou et al. [29], and Delic et al. [38], but in contrast to the studies carried out by Bajunaid et al. [27] and Basnet et al. [18], where the ear to eye distance showed less significant correlation with the chin to nose distance. The present study showed a moderate positive correlation of the chin to nose distance with both right and left pupil to rima oris distance (right r = 0.660, left r = 0.670), which was statistically significant (p value < 0.01), as shown in Table 3. This supports a previous study carried out by Basnet et al. [18], but is in contradiction to the studies carried out by Tina-Olaivar [30] and Nagpal et al. [1], which showed little or no significance with the chin to nose distance.

The present study showed a weak positive correlation of the chin to nose distance with the glabella to subnasion distance (r = 0.417), which was statistically significant (p value < 0.01), as shown in Table 2. This supports a previous study carried out by McGee [23] but contradicts the study carried out by Nagpal et al. [1]. In general, variation in the facial measurements is seen because of the diversity in geographical location and historical background. It is also seen due to difference in the ethnicity of the sample population tested.

By using this method, it is possible to restore correct VD in patients, which will be harmonious with the upper half of the face. The limitations of the present study were that the sample size was very small to conclude the findings. The external facial landmarks, especially soft tissue landmarks (length of lower commissure, lip and philtrum), may be subjected to age-related changes. The study was restricted to the subjects with class I jaw relation. Other skeletal or dental malocclusions were not considered. There was no inclusion of the various ethnic groups. There need to be further investigations to endorse or refute the findings of the present study.

5. Conclusions

Within the limitations of the study, it can be concluded that there exists a highly positive correlation between the chin to nose distance and the distance between both the right and left lateral corner of the mouth to the outer canthus of the eye, and the distance between both the right and left ear to the eye. Hence, these measurements can be used as an adjunct for establishing VDO in the edentulous patient.

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