

# Development and validation of software using artificial intelligence to predict lost vertical dimension in partially and completely edentulous patients - *A cross sectional study*

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## Abstract

### Introduction:

The vertical dimension of occlusion (VDO) determination is an important procedure in the process of prosthodontic treatment, especially among partially and fully edentulous individuals. Traditional approaches in VDO evaluation may lack reliability and have significant differences in clinical results. Recent developments in AI and machine learning have brought new opportunities to enhance the accuracy of diagnosis in dentistry.

### AIM:

To develop and validate an artificial intelligence-based software for predicting the lost vertical dimension of occlusion using anthropometric parameters.

### Materials and Methods:

A total of 1000 participants participated in this cross-sectional study. Anthropometric parameters and the value of VDO using the Niswonger's method in 800 participants with complete teeth were considered to develop the AI-based software. Validation of the software was done on 200 subjects, out of which 100 had partial teeth with decreased VDO, and 100 had no teeth at all. Predicted VDO values were statistically compared with those determined by the conventional technique. SPSS version 26.0 was employed for statistical analyses using the independent t-test and Pearson correlation test ( $p \leq 0.05$ ).

### Results:

The mean VDO measured through the traditional technique was  $65.20 \pm 6.30$  mm, whereas the mean VDO calculated from the AI-powered program was  $64.92 \pm 6.65$  mm. There was no significant difference between the two techniques ( $p = 0.866$ ). There existed a high positive correlation between the two approaches ( $r = 0.987$ ,  $p < 0.001$ ).

### Conclusion:

The AI-based software was found to be accurate in predicting lost VDO in comparison to the conventional method. The AI-based software may be used as an auxiliary tool to calculate VDO in partially and completely edentulous patients.

### Keywords:

Artificial intelligence; Vertical dimension of occlusion; Anthropometry; Machine learning; Prosthodontics

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## INTRODUCTION

Vertically Dimension of Occlusion (VDO) is one of the significant measurements in the

rehabilitation process. It plays a critical role in cases where a patient has lost their posterior teeth

or suffered from severe tooth wear. Calculation of accurate Vertical Dimension of Occlusion helps lay down the framework for successful prosthetic rehabilitation.<sup>1</sup>

Several methods for estimating the VDO have been developed both before and after extraction. These include intraoral assessment, profiling, and cephalometric study prior to extraction, and include mandibular rest posture, anthropometrics, current dentures, phonetics, swallowing pattern, and facial esthetics following extraction.<sup>2</sup>

Clinical consequences that may occur if important factors, such as achieving proper occlusion, space for restorations, and aesthetics, are neglected and OVD is altered include angular cheilitis, phonetic alteration, alteration of the minimum speech space, pain at the level of the edentulous ridges, and temporomandibular joint (TMJ) dysfunctions. There is still no widely accepted agreement or scientific consensus regarding the method of assessment, and it is still challenging to determine the OVD in everyday practice, especially in patients who are completely edentulous.<sup>3</sup> The reliability of anthropometric methods for determining the vertical dimension of occlusion has been well studied in the literature. The first anthropometric measurements were noted by Leonardo da Vinci, who also provided simple ratios for facial representation. They were later employed by Wills, Ivy, and Goodfriend as a simple, inexpensive, and non-invasive technique.<sup>2</sup> Previous studies have connected VDO to a number of facial and physical features, including the glabella to subnasion distance, the right and left pupil to rima oris distance, the right and left lateral corner of mouth to outer canthus of eye distance, and the right and left ear to eye distance.<sup>4</sup>

From a scientific perspective, the traditional methods, such the evaluation of facial appearance, are non-specific even though they could look good on a subjective level. However, objective methods like electromyography and biting forces need complex equipment that is impractical for daily use.<sup>5</sup>

Imaging modalities, computer-aided design and manufacturing (CAD/CAM), cone-beam computed tomography (CBCT), three-dimensional facial scanning, and, more recently, artificial intelligence-based diagnostic tools have all advanced significantly during the last ten years.<sup>6</sup>

Artificial intelligence (AI) is growing in popularity worldwide due to its significant impact on research and innovation. The application of AI in prosthodontics has increased significantly over the past few years. AI is utilized in diagnosis, decision-making, prognosis, treatment planning, and outcome prediction. AI can be used in prosthodontics to increase dental practice's accuracy and precision.<sup>7</sup>

Specialized software packages are necessary to

determine VD digitally. Furthermore, digital software provides precise measurements and significantly lowers human error, which ultimately saves doctors' time and enhances the complexity of clinical work.<sup>6</sup>

Therefore, the present study aims to develop and validate a software system using artificial intelligence by machine learning to predict lost vertical dimension of occlusion in partially and completely edentulous patients through a cross-sectional study design. By integrating anthropometric measurements and AI-based predictive modeling, this study seeks to provide a reliable, reproducible, and clinically applicable decision-support tool to assist prosthodontists in determining VDO with greater accuracy and consistency.

#### **SAMPLE SIZE- 1000**

1. Out of which 800 dentate participants to develop software will be taken.
2. And 200 patients 100dentulous (with lost VDO) and 100 edentulous will be taken to validate the software.

#### **MATERIAL AND METHODS**

##### **Study Design and Ethical Approval**

An AI-based software program that helps predict the lost vertical dimension of occlusion (VDO) in partially and totally edentulous individuals was designed and validated in this cross-sectional study. This study received approval by the Institutional Ethics Committee. The subjects enrolled in this study were provided written informed consent before participation.

##### **Study Population and Sample Size**

A total of **1000 participants** were included in the study. The sample was divided into two groups:

- **Development group:** 800 dentate individuals with normal occlusion
- **Validation group:** 200 participants, comprising:
  - 100 dentulous individuals with reduced VDO
  - 100 completely edentulous patients

Participants were selected based on predefined inclusion and exclusion criteria.

##### **Inclusion Criteria**

- ☐ Fully dentated subjects with established occlusion (development group)

- Patients with decreased VDO clinically due to attrition, tooth loss, or wearing of teeth (validation group)
- Edentulous subjects who require prosthodontic treatment

#### **Exclusion Criteria**

- Presence of any craniofacial abnormalities or deformities
- Any history of maxillofacial surgery or injury
- Any problems with temporomandibular joint
- Neuromuscular disorders affecting mandibular movements

#### **Anthropometric Measurements**

Five anthropometric parameters were recorded for all participants using a digital Vernier caliper.

1. Distance from lateral canthus of the eye to the corner of the mouth
2. Distance between the thumb and index finger (hand span)
3. Distance from exocanthion to external auditory meatus
4. Length of the auricle
5. Finger length:
  - Thumb length in males
  - Little finger length in females

All measurements were recorded in millimeters by a single calibrated examiner to minimize interobserver variability.

#### **Determination of Vertical Dimension of Occlusion**

The vertical dimension of occlusion (VDO) was determined using **Niswonger's method**, which involves measuring the vertical dimension at rest (VDR) and subtracting the freeway space (2–4 mm) to obtain VDO.

#### **Development of AI-Based Software**

The VDO prediction model based on AI was created through supervised machine learning methods.

- Programming environment: Python (Jupyter Notebook)
- User Interface: Streamlit
- Deployment: Pyngrok

#### **Model Development**

Anthropometric measurements were utilized as input data, whereas the output data included the calculated VDO based on the method of Niswonger.

Data preprocessing included:

- Handling missing values
- Normalization of data
- Outlier detection

The dataset (n = 800) was split into:

- Training set (80%)
- Testing set (20%)

A Multiple linear regression model was trained to predict VDO.

#### **Model Evaluation**

Model performance was assessed using:

- Mean Absolute Error (MAE)
- Root Mean Square Error (RMSE)
- Coefficient of determination ( $R^2$ )

K-fold cross-validation ( $k = 5/10$ ) was performed to prevent overfitting.

#### **Validation of AI Model**

Validation of the AI model was done using an independent population of 200 subjects.

Anthropometric parameters of these subjects were fed to the AI program to estimate VDO and compared with VDO calculated based on Niswonger's traditional technique.

#### **Statistical Analysis**

SPSS software version 26.0 was used for statistical analysis.

□ Normality of data was tested using Kolmogorov-Smirnov test

□ Independent t-test was applied for comparison of mean VDO values from the two methods

□ Pearson's correlation coefficient was applied to examine the correlation between the two methods

P value  $\leq 0.05$  was taken as statistically significant.

### AI Based VDO Prediction System

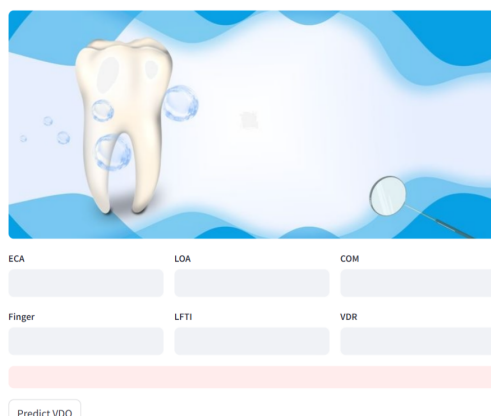


Figure 1 - Showing display of the software program- AI based VDO prediction system.

### RESULT

SPSS software v26.0 was used to analyze the data. The significance level was maintained at 5%. The Kolmogorov-Smirnov test was used to evaluate the data's normality, and the results indicated that the data had a normal distribution. An independent t test was used to compare the lost VDO readings between the two approaches. The Pearson correlation test was used to examine the relationship between the lost VDO measurements made using the two techniques.

#### Comparison of the lost VDO measured using the conventional method and software

| Metho<br>d       | Mean<br>VDO | S<br>D | SE<br>M | Diffe<br>rence | t-<br>val<br>ue | p-<br>val<br>ue |
|------------------|-------------|--------|---------|----------------|-----------------|-----------------|
| Conve<br>ntional | 65.20       | 6.30   | 1.15    | 0.28           | 0.169           | 0.866           |
| Softwa<br>re     | 64.92       | 6.5    | 1.21    |                |                 |                 |

#### Independent t test

An independent t-test is used to compare the lost vertical dimension of occlusion (VDO) measured with software and conventional methods. The conventional method yields a slightly higher mean VDO (65.20 mm) compared to the software method (64.92 mm), but the difference is minimal. A high p-value ( $>0.05$ ) means the difference is not statistically significant. This suggests that both methods provide similar results with no meaningful discrepancy.

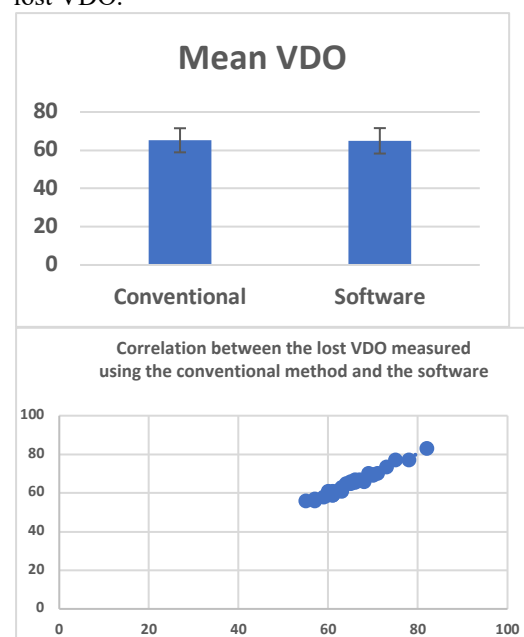
#### Correlation between the lost VDO measured using the conventional method and the software

| Method | r-value | p-value |
|--------|---------|---------|
|--------|---------|---------|

| Conventional | 0.987 | $<0.001^*$ |
|--------------|-------|------------|
|--------------|-------|------------|

Pearson correlation test; \* indicates a significant correlation at  $p \leq 0.05$

This table presents an analysis of the correlation between the lost VDO measured using the conventional method and the software. The results indicate a very strong positive correlation ( $r = 0.987$ ) between the lost vertical dimension of occlusion (VDO) measurements obtained using the conventional method and software. This suggests an almost perfect linear relationship between the two measurement methods, meaning the values obtained from one method closely predict the values from the other. Because the correlation is very high and statistically significant, this suggests that the software provides results closely matching the conventional method. This reinforces that the software can be a reliable alternative for measuring lost VDO.



### DISCUSSION

Accurate determination of lost vertical dimension of occlusion is a critical component of successful prosthodontic rehabilitation, particularly in partially and completely edentulous patients. Despite the availability of numerous conventional methods, the absence of a universally accepted, objective, and reproducible technique continues to pose a challenge for clinicians. The present study aimed to address this limitation by developing and validating an artificial intelligence-based software system for predicting lost VDO using anthropometric parameters.

The results of the present study demonstrated that the mean lost VDO values predicted by the AI-based software closely matched those obtained using the conventional Niswonger's method, with no statistically significant difference between the

two methods. This finding suggests that the AI-based approach can reliably estimate lost VDO with accuracy comparable to that of established clinical techniques.

The extremely high positive correlation ( $r = 0.987$ ) between the conventional and software-based methods further adds to the validation of the developed software. This high level of positive correlation between the two methods indicates that the AI model was able to effectively learn and integrate various anthropometric parameters to predict lost VDO in a manner consistent with clinical judgment. The above findings are in agreement with previous anthropometric studies that found significant correlations between VDO and facial or hand measurements.

Basutkar et al. found strong correlations between VDO and finger length measurements, which emphasize the importance of anthropometric landmarks in providing objective guidance.<sup>1</sup>

Similarly, Ladda et al. found a reliable relationship between interpupillary distance and VDO, validating the concept that facial proportions can be used to predict VDO.<sup>9</sup> However, most previous anthropometric studies were based on limited anthropometric parameters and were affected by gender, ethnicity, and facial morphology.

Recent advancements in digital dentistry and artificial intelligence have allowed for the inclusion of various factors in predictive models, minimizing dependence on operators and subjective biases. Investigations on digital facial scanning have demonstrated high correlations between clinical and digital measurements, indicating the potential for digital preservation of facial measurements in the long term.<sup>10</sup>

The present study has taken this further by including artificial intelligence in the assessment of anthropometric measurements to improve the accuracy and reproducibility of the results.

Artificial intelligence and machine learning are becoming more and more important in dentistry for predictive measures, diagnostics, classification and identification, and many other qualities. Artificial intelligence models have been developed to help dentists and dental surgeons with a variety of tasks, including the creation of fixed denture prostheses that resemble natural teeth, the classification of partially edentate arches, the prediction of functional outcomes, and removable partial dentures. Artificial intelligence models have also been used by virtual articulators to accurately forecast VD.<sup>6</sup>

In their research on orthodontic machine learning: Automated facial analysis of vertical dimension for greater precision and efficiency, Rousseau et al. came to the conclusion that machine learning has the capacity to perform dependable and readily repeatable analyses on sizable image datasets. This novel technique offers opportunities for further progress in clinical orthodontics and research.<sup>11</sup>

Helmy et al. found that the reliability and agreement of AI-assisted cephalometric measures with traditional clinical techniques for VDO assessment justified their application in digital prosthodontic workflows.<sup>12</sup>

Another study by Abdelmagid et al. found that an AI-driven YOLOv8 model showed good diagnostic accuracy and agreement with human assessment, indicating its potential as a reliable and unbiased tool for automated evaluation of anterior vertical relationships.<sup>13</sup>

However, there isn't much research on AI-based lost VDO predictions. By demonstrating that AI-based software can be utilized as a dependable supplement to conventional clinical prosthodontics techniques, the current work contributes to this emerging field of inquiry.

Some of the limitations of the study, which should be kept in mind for future research, include the fact that it is a cross-sectional study, and the AI model used is based on anthropometric data of one population only. Future studies should be conducted on multiple centers, including different ethnic groups, for better validation of the software.

## CONCLUSION-

Within the limitations of the present study, it can be concluded that the artificial intelligence-based software for the prediction of lost vertical dimension of occlusion was found to have high accuracy and a high degree of agreement when compared to traditional clinical methods for VDO prediction. Lack of statistically significant difference between the two methods and a very high degree of positive correlation between the two methods suggest that the software is a reliable and reproducible tool for estimating lost VDO in partially and completely edentulous patients.

The use of artificial intelligence in prosthodontic diagnostic procedures can prove to be a valuable tool in conjunction with traditional methods for VDO prediction. Such an AI-based software for VDO prediction can prove to be a valuable tool in the field of prosthodontics.

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