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A STANDARDIZED METHOD TO DETERMINE THE PROPER WORKING DISTANCE FOR DENTAL MAGNIFICATION UTILIZING NEUTRAL ERGONOMICS POSITIONING

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ABSTRACT

Introduction Evaluate and compare the relationship between anatomic measurements of the dental clinician in a neutral ergonomics position with the proper working distance and test the hypothesis that working distance can be estimated using specific anatomical measurements of the operator.

Materials and Methods Specific measurements were obtained from 134 participants utilizing a neutral ergonomics position. Values were applied using the Pythagorean theorem to calculate a hypothesized working distance (HWD) from lateral epicanthus (E) to antecubital fossa (F) and antecubital fossa to the tip of the thumb (T). The actual working distance (ET) was measured from lateral epicanthus to tip of the thumb in a neutral ergonomics position in a simulated setting.

Results The results showed a significant positive correlation between (ET) and (HWD) and a positive correlation for all of the anatomic measurements taken in simulation: ET to height and HWD to height; (EF) and ET, EF and HWD; antecubital fossa to the thumb (FT) and ET, FT and HWD ($p<0.00$). There was a marginally significant difference when comparing vision types, corrective and non- corrective ($p<0.058$), with non-corrective vision having a higher actual working distance. There was a statistical difference when comparing gender and HWD with male participants ranking higher hypothesized and actual working distance.

Conclusion When applying the Pythagorean formula using anatomic landmark measurements, the HWD is repeatable for most operators and may contribute to a more standardized method to measure the accurate working distance that fits the ergonomics.

KEYWORDS

Ergonomics; Dental Education; Musculoskeletal Disorders; Dentist; Dental Hygienists.

1. INTRODUCTION

Proper ergonomics in dentistry have been viewed as contributory aspects in the prevention of musculoskeletal injury and the working distance with magnification should allow the operator to maintain optimum posture [1]. Many dental students and clinicians may not be aware of what constitutes the correct ergonomics posture. The importance of an early introduction to proper ergonomics may be beneficial to a clinician's career, for both comfort and longevity. The cause of musculoskeletal disorders (MSD) is multifactorial and can develop from as little as a single event, or more likely through repetitive

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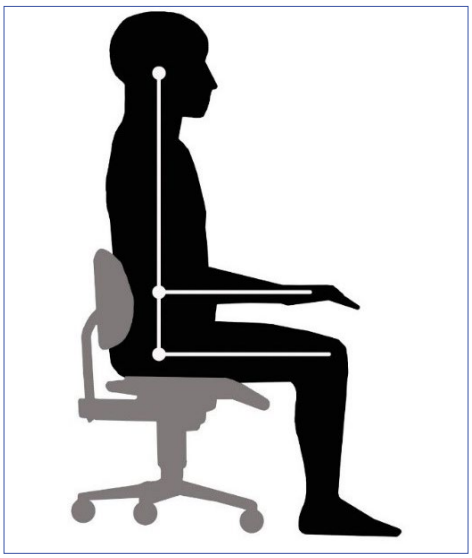

Figure 1. Clinical position based on Module 1 Section 3 of *Fundamentals of periodontal instrumentation and advanced root instrumentation*. 8th edition revised by Gehrig JS, Sroda R, Saccuzzo D. Philadelphia, PA: Wolters Kluwer; 2019.

Figure 2. The theorem application: **a)** The Pythagorean theorem is the formula for calculating the length of one side of a right-angled triangle (c) when the length of the other two sides is known: $a^2 + b^2 = c^2$. In this formula, c represents **the hypothesized working distance**, **a** represents the distance from **"Eye to Elbow"** and **b** represents the distance from **Elbow to Tooth; b)** Investigational theorem application performed on the researcher.

occupational movements over time. However, risks for the development of MSD have been identified among dental students with reports of pain in the back and neck regions during training [2]. In an earlier study on the prevalence of body pain in a dental student population, 46-71% of students reported pain with the percentage increasing with the increase of years in school [3]. The prevalence of musculoskeletal disorders in the dentist's necks, backs, shoulders, and arms were higher than other areas of the body; intervention with magnification helped to improve the working conditions reducing discomfort for the clinicians [4]. Those who reported the regular use of some type of magnification were significantly less likely to report MSDs compared to those who used magnification occasionally or never [5]. There is a general acceptance of the use of magnification by dental students and practitioners and it is widely perceived as an adjunct, if not a standard, for dental care in the profession. Recommendations by The Council on Dental Practice's (CDP) Dental Wellness Advisory Committee (DWAC), in conjunction with the ADA Health Policy Institute, stress proper diligence when choosing loupes and the importance of the magnification level, working length, field of view, and the angle of declination in order to maintain good head and neck posture [6]. Measurements are individualized and unique to the clinician.

Magnification can allow the clinician to better visualize the oral cavity and to reinforce the maintenance of neutral ergonomics. The use of dental magnification in dentistry is widely utilized and continued efforts to support its role in maintaining work posture remains an area of study. Employing magnification loupes has led to a reduction in the intensity of discomfort felt by dentists in areas of the "neck, shoulders and arms, back, elbow, forearm and the whole body" [4]. Magnification increases a clinician's visual acuity within the oral cavity and allows the clinician to see detail without compensating with improper bending or positioning. If magnification is to be considered

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Table 1. Data Collection Criteria.

Participant's Age:				
Participant's Gender:	**Male**	**Female**	**Do not wish to answer**	
Participant's Educational Status:	**D1**	**D2**	**D3**	**Faculty**
Handedness	**Right**		**Left**	
Standing Height (inch)				
Do you wear glasses/contacts? Lasik or related procedure?	**Yes**		**No**	
EF lateral epicanthus of the eye to mid-elbow fold (inch)				
FT The mid-elbow fold of the cubital fossa to the tip of thumb and or to occlusal surface #19 or #30 (inch)				
ET Working distance without loupes lateral epicanthus eye to typodont mandibular molar (inch)				

Table 2. Correlation significance test.

Pearson Correlation	r	Sig. (2-tailed)	statistic
ET vs HWD	0.878	0.000	Significant
ET vs Height	0 .741	0.000	Significant
HWD vs Height	0.847	0.000	Significant
EF vs ET	0.854	0.000	Significant
EF vs HWD	0.956	0.000	Significant
FT vs ET	0.732	0.000	Significant
FT vs HWD	0.862	0.000	Significant

*Correlation is significant at the 0.01 level (2-tailed).

an element in maintaining proper ergonomics, the ideal working distance with magnification cannot be ignored. The necessary working distance needed with magnification was credited with contributing to the positive effect and improvement among dental students by reinforcing the maintenance of proper ergonomics for the head, neck, and trunk [7].

As only one adjunct to achieving this goal, dental magnification has its many intricacies within itself. Proper alignment of declination angle and working distance can be viewed as essential in affirming this contribution. Working distance measurements may be more variable, depending on how the measurements are taken and obtained. Although the ideal working distance needed can fall within a range dependent on the magnitude of magnification (ie: 2.5x, 3.0x, 3.5x.etc), the working distance measurement/ focus point in this range may vary. A standard to obtain the most optimal measurement to help minimize the variation may be applicable and helpful in determining an ideal working distance specific for an individual.

The working distance is measured from the clinician's eyes to the operating site. It is of critical importance since it reflects an individual length impacted by an operator's characteristics and the ability to maintain proper ergonomics while working. Maintaining proper ergonomics can be found in the curriculum of dental education as provided in a guide to neutral ergonomics [8]. Improper measurements may allow for awkward static positions and forward bending. Studies have indicated that participants expressed that loupes resulted in better vision, more comfort, a positive change in work posture [7], and improved working conditions that facilitated their work [4].

Of the current research available, emphasis on achieving the proper individualized working distance is scarce and further research is warranted to determine how an individual's characteristics may influence the necessary working distance for proper ergonomics positions in the selection of magnification loupes.

The following null hypotheses were tested:

1) There is a direct relationship between the specific anatomical measurements of a dental operator while in neutral ergonomics position and a mathematical determination of proper working distance which can be obtained

2) No difference in working distance between the corrective and non-corrective vision groups, and

3) No difference in working distance between genders.

2. MATERIALS AND METHODS

Participants were recruited through LECOM School of Dental Medicine by email invitation after getting the IRB approval for the study protocol. All D1, D2, and D3 students were asked to participate in the study. In addition, the dental faculty were invited to participate. Invitation to participate was not extended to the D4 students since their curriculum places them in outreach clinics of distant locations.

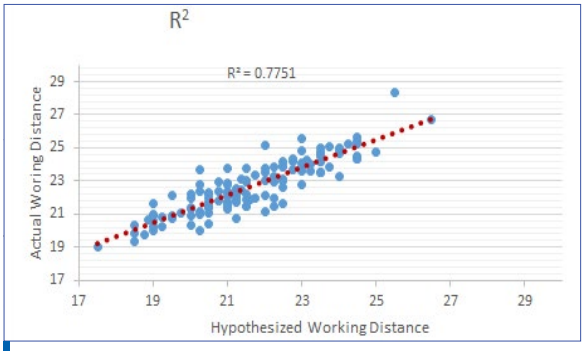

Figure 3. Strong linear correlation between HWD and ET. Distance in inches.

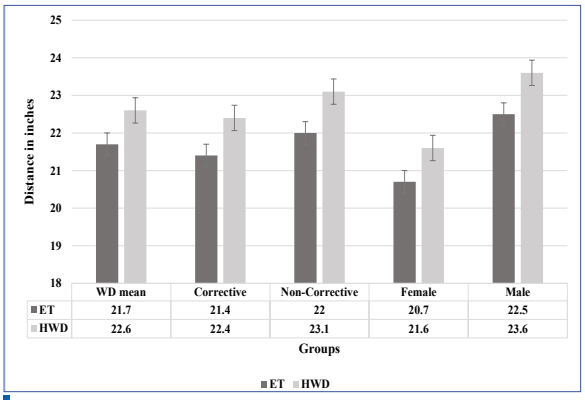

Figure 4. Group descriptive statistics.

contacts, glasses, or has had any corrected vision operation. The measurements were collected with a right-angle square and measuring tape in inches which can measure up to one eighth of the inch. Following demographic data collection, the participant was seated at a simulation station and instructed to assume the 9 o'clock position for right-handed participants and 3 o'clock for left-handed participants. The participant was given safety goggles to wear for the duration of the experimental session. The participant was asked by the student investigator and principal investigator to adjust the mannequin's head to be at waist level. The participant was instructed into neutral ergonomics based on Module 1 Section 3 of Fundamentals of periodontal instrumentation and advanced root instrumentation. 8th edition revised by Gehrig JS, Sroda R, Saccuzzo D. Philadelphia, PA: Wolters Kluwer; 2019. (Fig. 1).

- Step 1: Place buttock back in the chair with even distribution on the seat.
- Step 2: Adjust chair height so that feet rest flat on the floor. Spread feet to shoulders width apart and directly in front of the hips.
- Step 3: Tilt the seat until the back edge is one inch higher than the front edge or utilize a wedge-shaped ergonomics cushion.
- Step 4: Adjust the lumbar rest so the lower back is supported when the buttock is back in the chair.
- Step 5: Adjust lumbar rest so that the height supports your natural curve.
- Step 6: Raise the tail bone to establish correct spinal curvature.
- Step 7: Stabilize the lower back by pulling in the stomach muscles to the spine.
- Step 8: Relax shoulders down and back.
- Step 9: Position arms along the long axis of the torso and hold elbows near the body.

Student investigators and the principal investigator observed and verbally instructed changes in ergonomics keeping in mind the following recommendations:

- Head tilt of 0 to 20 degrees
- Trunk flexion of 0 to 20 degrees
- Torso in line with the long axis of the body
- Shoulders in a horizontal line
- Elbows at waist level held slightly away from the body, no greater than 20 degrees from the body
- Forearm position held parallel to the floor, the angle between 100 degrees and 60 degrees
- Wrist aligned with a forearm; little finger-side of the palm is slightly lower than the thumb side of the palm.

Once neutral ergonomics were achieved and confirmed by the investigators, the participant was asked to maintain this position while focusing on the occlusal surface of tooth 46 within the mannequin for right-handed participants and the occlusal surface of 36 for left-handed participants. For every experimental session, a minimum of three investigators were present to assist in measuring and recording the data. Three measurements were recorded:

1) EF: From the lateral epicanthus of the eye to the mid-elbow fold of the cubital fossa.
2) FT: From the mid-elbow fold of the cubital fossa to the tip of the thumb and or to the occlusal surface of #46 for right-handed participants and #36 for left-handed participants.
3) ET: From the lateral epicanthus of the eye to the typodont lower molar. The right-angle square was used to help maintain an angle consistent with our proposed hypotheses in the equation and record measurements from EF and FT. A measuring tape was used to measure the observed working distance while the participant maintained an ergonomics position. The investigator notified the participant when the working distance measurement was initiated and completed. A student investigator recorded the participant's demographics on a password-protected computer within a password protected flash drive.

Using the Pythagorean theorem (Fig. 2) EF measurements were used to represent (a), FT measurements were used to represent (b), and (c) was solved as our HWD in the formula and recorded.

2.1. The participant was informed of the following risks:

According to the Institutional Review Board (IRB) protocol, the participant was asked to maintain a neutral ergonomics position for approximately up to five minutes. The participant was informed that they may experience minimal muscle soreness during

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or after the measurement session. To minimize this risk the participant was informed of their right to stop the session at any time. We asked participants to verbally announce muscle soreness during the session to both student researchers and verify that the position we measured from was comfortable. If the participant could not continue the session the previously recorded information would be discarded. The ruler edges were protected with a plastic tube to protect each participant and the student researchers. The ruler, measuring tape, and the participant's eyewear was disinfected with CaviWipes (Metrex™ Research, Orange, CA, USA) surface disinfectant pre-moistened wipe before and after each use.

2.2. Analysis

Both demographic and recorded measurements were analyzed to determine statistical significance based on individual characteristics with the application of anatomic measurements in neutral ergonomics and working distance. Levene's Test for Equality, Variances and t-test for equality of means was used for this study with Pearson's correlation sig. (2-tailed).

3. RESULTS

Levene's Test for Equality showed a significant difference when sig. (2-tailed) is ≤0.05. There was a marginally significant difference in vision type by "ET" to the vision; where the non-corrective vision had higher "ET" values compared to corrective vision values Sig.(2-tailed)= 0.058.

Significant differences were found (Sig. (2-tailed) =0.022) when comparing "HWD" between the corrective and non-corrective vision, where the non-corrective vision had higher HWD.

There was a highly significant difference in "ET" values by gender with males having significantly higher "ET" values than females. Sig.(2-tailed)=0.000

There was a highly significant difference in "HWD" by gender with males having a significantly higher "Hypothesized Working Distance" than females. Sig.(2-tailed)=0.000. There was a strong correlation between HWD "Hypothesized Working Distance" and ET "Actual Working Distance" (Linear regression= 0.775) see Fig. 3.

4. DISCUSSION

Our study involved obtaining measurements of subjects in anatomic position with proper ergonomics and using those values in the Pythagorean theorem to hypothesize an individual's working distance as the hypotenuse. The primary purpose of this investigation was to analyze the relationship between measurements in an anatomic ergonomics position and the individual working distance using the geometric principles of the right triangle (Fig. 2). The core of the objectives centers on neutral ergonomics and the use of magnification. Our study does not attempt to explain the comparative effectiveness of different styles of magnification [9], but to provide an emphasis on the proper working distance in conjunction with magnification. Neutral ergonomics is described as having the shoulders parallel with the floor, elbows close to the sides, and the patient's mouth at elbow height of the clinician [8]. This picture of neutral ergonomics as viewed in (Fig. 1) is observed to follow the geometry of a right triangle with the working distance projecting to be the hypotenuse. Our investigation aimed to place a participant in a simulated position in neutral ergonomics prior to measuring working distance. This was based on the support of studies that attribute MSD to improper ergonomics positioning and allowed us to view a working distance that would be most conducive to a participant in neutral ergonomics [1]. While in this position, the working distance was visualized and measured directly. The results of our study provided data to show that our hypothesized measurement derived indirectly from measurements of anatomical relationships had a significant positive correlation with our observed actual working distance measurement in the same position. Within that anatomic measurement, (ET) and (HWD) were also both positively correlated to an individual's height. When viewed separately each component of our equation EF, ET, and HWD also individually showed a significant positive correlation between itself and the observed actual working distance. Our results showed a significant difference in Eye to Tooth (ET) measurements by gender with males having significantly higher ET measurements than females. This appears to be explained by the higher average ET measurement in males of 22.49 inches versus females with 20.73 inches. Similarly, there was a significant difference in the Hypothesized Working Distance (HWD) with males having a significantly higher HWD than females. Again, the average measurements for males was slightly higher at 23.61 inches compared to females at 21.62 inches. The results also showed a positive correlation of HWD and ET to height in both the female and male participants giving more support that collectively an individual's anatomic proportions can help to determine a proper working distance. It is unclear if the differences in male to female anatomic measurements is contributory to the development of poor posture or MSDs; however, previous studies have cited an increase in reported MSDs in females compared to males. In a study on ergonomics in preclinical dental students, Kamal et al [10] reported differences in the postures of male and female participants without magnification, where female students had worse ergonomic ratings than males. They also observed a positive correlation between posture and reported pain for both female and male students with 89.1% of female students and 65% of male students reporting MS pain after

starting preclinical training. A marginally significant difference in vision type by ET was found where non-corrective vision had a higher ET than corrective vision. This finding cannot be definitively explained since our measurements were derived while the participant was sitting in neutral ergonomics and hypothesized from anatomic measurements. Further studies may be necessary to investigate the significance of corrective and non-corrective vision differences. Our interpretation of the results provides that our hypothesis was correct, and our working distance value obtained through anatomic measurements is similar to a measured working distance in neutral ergonomics. An individualized working distance correlating to a person's body proportions can accurately provide their expected working distance. This allows us to propose that ideal working distance can be reproduced consistently through the Pythagorean formula with measured values of the eye to the cubital fossa and the cubital fossa to the tooth. In addition, by using identifiable landmarks (ie: the outer canthus and antecubital fossa), one may be able to obtain these measurements to calculate the desired working distance assuming ergonomics position without the aid of simulation in a dental chair or with a mannequin. Furthermore, future applications of this study may assist in the development of standardized measuring methods, thus promoting bio ergonomic head and neck posture.

5. CONCLUSIONS

The results allow us to conclude that we can accept the hypothesis that there is a direct relationship to the specific anatomical measurements of a dental operator while in neutral ergonomics position and a mathematical determination of proper working distance can be obtained. When applying the principles of the Pythagorean theorem with specified anatomic measurements the hypothesized working distance has a significant positive correlation to a participant's actual measured working distance. This finding may contribute to a more standardized method to measure the working distance that fits the proper neutral ergonomics for the operator. The first null hypothesis was accepted, while the second and third hypotheses were rejected. Through this study, we are able to provide applicable information for students to reinforce proper ergonomics through the analysis of individual working distance values and the relationship to individual anatomic measurements in order to utilize adjuncts like magnification in dentistry.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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None.

AUTHOR CONTRIBUTIONS

HH: Take the existing design. Come up with some modifications which improve the sensitivity, and reduce the error percentage of the previous design. Writing the manuscript; Data collection and data analysis. SA, MM, AG: Data collection and data analysis; Writing the manuscript. MZ: Methodology, calculation of modifications, writing and reviewing the manuscript. NA: Methodology, calculation of modifications, writing and reviewing the manuscript, data analysis and data interpretation.

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Questions

1. In an earlier study on the prevalence of body pain in a dental student population, _____ of students reported pain with the percentage increasing with the increase of years in school.

❑a. 25-30 %;
❑b. 10-15%;
❑c. 46-71%;
❑d. 32-55 %.

2. All below are the null hypotheses tested in the study except one, which one is the exception?

❑a. There is a direct relationship to the specific anatomical measurements of a dental operator while in neutral ergonomics position, and a mathematical determination of proper working distance can be obtained;
❑b. No difference in working distance between the corrective and non-corrective vision groups;
❑c. No difference in working distance between genders;
❑d. No difference in the working distance when using different light.

3. In the study, the investigators observed and verbally instructed changes in ergonomics keeping in mind the following recommendation:

❑a. Head tilt of 0 to 20 degrees;
❑b. Head tilt 0-30 degrees;
❑c. Head tilt 0-10 degrees;
❑d. No head tilt.

4. In the conclusion, when applying the principles of the Pythagorean theorem with specified anatomic measurements, the hypothesized working distance has_____ to the actual working distance.

❑a. Non- significant correlation;
❑b. Significant positive correlation;
❑c. Significant negative correlation;
❑d. Borderline significance.