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Selecting the Best Measuring Device to Evaluate the Dimensional Changes in Complete Denture Samples

Sanaa Rasheed Abd Al-Aaloosi[1], Ghasaq Abdullah Mohmood[2], Mustafa Sameer Mahmood Al-Shaikhli[3]

[1]*Department of Dentistry, AL-Rafidain University College, Baghdad, Iraq*

[2] *College of Dentistry, University of Bilad Alrafidain, Diyala, Iraq*

[3]*College of Dentistry, Al-Bayan University, Baghdad, Iraq*

Abstract

Objectives: Evaluating the accuracy of measuring tools used to access dimensional stability of complete denture samples.

Materials and Methods: Ten maxillary complete denture bases were made from heat-cure acrylic resin. Six reference points were prepared in each sample in the central incisors area, first premolars area, and first molars area. The distances between 5 different locations (3 horizontal distances and 2 anteroposterior distances) were measured using 3 different measuring tools. Each sample was measured three times using measuring microscope, sagittal cephalometric radiograph in conjunction with auto CAD soft-ware, and Vernier caliper. The results were analyzed using One-way ANOVA and post Tukey test.

Results: the type of measuring tool significantly affect the measurements especially with the radiographs that showed larger values compared to the microscope and Vernier caliper (P<0.05). The latter two measuring tools were equivalent to each other (P >0.05).

Conclusions: within the limitations of the present study, the measuring microscope is the best tool to be used for measuring distances as it provides the best visibility and validity. Vernier calipers is a better alternative for the microscope compare to the radiographs and computer software.

Keywords: Dimensional Stability; Complete Dentures; Measuring Tools; Dimensional Accuracy; Micrometer Microscope.

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Email: sanaa.rasheedelc@ruc.edu.iq

Introduction

Dimensional accuracy is an important physical property for a complete denture base material to ensure that the denture base maintains its shape during function and over a period of time [1]. Dimensional stability or accuracy is usually conducted using measuring tools ranging from simple Vernier calipers like instruments to comparators and microscopes. Measurements are designed to answer quantitative questions, such as “How much the intended denture base sample had been changed when subjected to the variables of a given study?” these quantitative pieces of information are usually obtained through the use of measurement tools. In many research and development laboratory situations, microscopes are selected because at low throughput levels, they offer the highest accuracy and best color fidelity of any method of optical measuring. Other important technologies include optical comparators, video-based measuring systems, and computer soft-wares.

Three different types of measuring tools were used in studies including dimensional stability and these are: 1. Optical comparators based on the travelling

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microscope were used in 60%; 2. 25% of studies used a simple hand-held caliper instrument; 3. the remainder of studies employed a variety of techniques ranging from subjective non-parametric techniques and simple measurement determination using feeler gauges to the sophisticated moiré topography [2]. In the last 30 years with the development of digital era, studies showed a variety of measuring methods. The Michigan Computer Graphics Coordinate Measuring System (MCGCMS) was designed to fulfill the requirements of a measurement method that is needed to evaluate the denture bases, and these are validity, reliability, and sensitivity. This system was a computer-based measuring method and it was providing a sensitivity of 1 µm and reliability of ±3µm [3,4]. Shukor et al used a video camera linked to a computer to record the measurements of a specific reference points in maxillary complete denture samples. A calibration slide was used to calibrate the system before measuring each group of dentures (1). Another method of measurement employed the use of auto CAD software on digital radiographs or photographs to measure the distance between radiopaque reference points on the artificial teeth in maxillary and mandibular complete dentures [4,5].

Lee et al used a unique method to observe the gap between the denture base and its respective cast. Computerized tomography (CT) was used for each denture and its respective master cast that had been studied. The CT images were obtained at a scanning interval of 0.6mm from the anterior to posterior areas [6]. Most recent studies involve the use of a video base measuring systems and soft-wares to evaluate the dimensional stability of the complete denture samples [7].

With the new CAD-CAM evolution and 3D printing, measurements could be conducted using digital scanners to digitalize samples to stereolithography (STL) files. Those files were compared to the corresponding original one, with the best file alignment function, using a matching software that was specifically designed for that purpose [8].

Despite these sophisticated computerized coordinate measuring systems; the classical apparatus for measuring the dimensional accuracy had been used also in recent studies. Ranging from digital Vernier caliper [9], traveling microscope [10–16], to optical and digital micrometers [17–19].

The purpose of this study was to evaluate the effect of using different measuring devices (tools); specifically, the Vernier caliper, measuring microscope, and computer software; on the accuracy of linear dimensional stability of complete denture base samples. The null hypothesis was that the type of the measuring tool would not influence the results of the dimensional stability studies.

Material and Methods

Three measuring apparatuses were selected for this study; the conventional measuring microscope (travelling micrometer microscope) accurate to 0.005mm (Leitz/WETZLAR, Berlin, Germany); Sagittal cephalometric projections (digital image) using the DIMAX 3.2.1 Digital system (PLANMECA, Helsinki, Finland). The exposure time set to 23 sec, the enhanced resolution was selected at 60 KVp (Kilovolt) and 10mA (milliamperes) were used. Later, the distances between the selected reference points of the digital image were measured using Auto-Cad software. The third method of measurement involve the use of a digital Vernier caliper accurate to 0.05mm (Shanghai Shenhanme asuring tools Co., LTD, China).

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Ten maxillary denture bases had been prepared from heat-cured Poly Methyl Methacrylate (PMMA) (Regular, Vertex-Dental, Soesterberg, Netherlands) to be the samples for this study, and they have been prepared according to the recommendations of the manufacturer. The samples measured three times to evaluate the accuracy of the selected measuring tool. Sample grouping was performed as; the M group which represents the Measuring microscope (Control group); the X group which represents the X-ray or sagittal cephalometric images; and the V group which represent the digital Vernier caliper; both two groups are the experimental groups. The samples were prepared as follows:

Ten maxillary edentulous casts were made from Type III dental stone (Elite model, Zhermack technical, Polesine, Italy) mixed with water according to the recommended w/p ratio (30ml/100g) and poured into an ideal negative rubber mold (Columbia dentoform Corp., New York, USA) that represent upper edentulous arch. Pouring was accomplished using the vibrator, and each cast was left undisturbed for 45 min. and then separated from the mold. A record base was constructed from thermoplastic acrylic cakes BIOCRYL® (SCHEU-Dental, Iserlohn, Germany) using Biostar machine (SCHEU-Dental, Iserlohn, Germany) manipulated according to the manufacturer's instructions. Thus, an even thickness of 4 mm [20] for the record base was obtained for all samples. These record bases had been sealed with wax to the cast to be prepared for the flasking procedure. Every record base and cast were flasked conventially for compression molding technique using a standard metallic flask.

To measure the linear dimensional stability, reference points were prepared on the top surface of each denture base and these were: two in the area of each central incisor and referred to as Right Incisor -Left Incisor (RI-LI); two in the area of the first premolar on both sides of the arch and they were represented as RPM-LPM, and another two in the area of the first molar region on both sides and they referred as RM-LM [21]. Six holes were prepared using a small round bur in a slow-speed contra-angle handpiece and then modified with a fissure bur. These cavities had been filled with amalgam restorations and burnished very well until they appeared smooth and round. A thermoplastic acrylic cake BIOCRYL had been compressed above the first sample, after preparing the reference points, to be used as a guide for preparing identical reference points for all samples. Holes were drilled in this thermoplastic cake above each reference point of the first samples. These holes were used as a guide to duplicate the position of each reference points and make all distances identical in all samples.

Measurement procedures was conducted as follow:

1. The distances between RI-LI, RPM-LPM, RM-LM, RI-RM, and LI-LM reference points (Figure 1) were measured using a Measuring microscope accurate to 0.005mm (Figure 2).

FIGURE 1. The measured distances.

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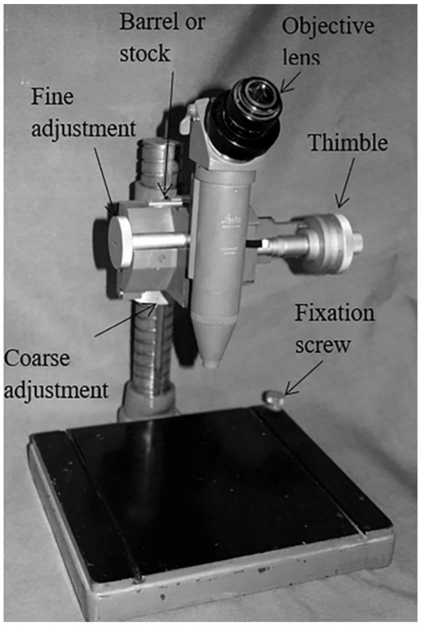

FIGURE 2. The micrometer microscope.

The sample was placed on the base of the microscope and its position was modified until the reference point (with round cross-section) became tangent into two lines of the cross (Figure 3). The right reference point would be placed in the upper right quarter of the cross and the left reference point would be placed in the upper left quarter of the cross and the distance between them had been measured by turning the thimble so the body of the microscope, that holds the objective lens, would be moved against the barrel or stock (ruler) which has an extent of 50 mm. Each full turn of the thimble would move the body 1 mm. The thimble has 10 divisions which represent 0.1 mm and each one was divided into further subdivisions which represent 0.01 mm. The distance between two subdivisions can measure 0.005 mm, which represents the accuracy of the measuring microscope. The average of three measurements was recorded as the distance between the points.

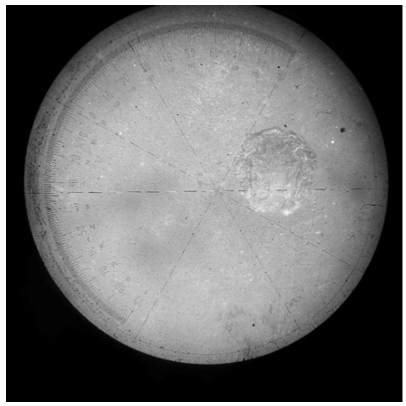

FIGURE 3. Reference point under the measuring microscope.

2. The Sagittal cephalometric projections (digital image) for maxillary record bases were made so a top view of the sample had been exposed to X-ray beam. Later, the distances between the same reference points, showed in the digital image, was measured using AutoCAD software (Figure 4).

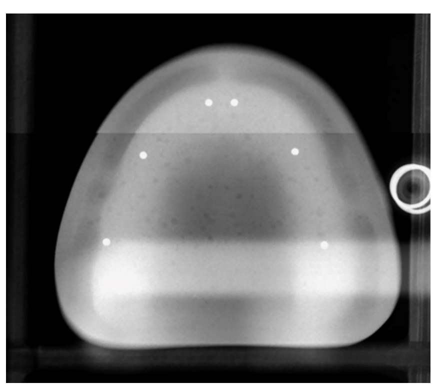

FIGURE 4. Cephalometric image for the samples.

3. The same samples and same distances were measured for a third time with a digital Vernier caliper accurate to 0.05mm and bare eyes. The internal jaws of the caliper were used to measure the distance between the reference points by making them tangent into the internal circle of the reference points. The measurements were performed three times for each two reference points and the mean value was used in the statistical analysis.

Results were statistically analyzed using IBM SPSS Version 25 for Windows operating system (SPSS Inc., Chicago, IL, USA). All data were subjected to a normality test with Shapiro- Wilk test for each group. One-way analysis of variance (ANOVA) with post hoc Tukey's honestly significant difference (HSD) was performed. The significance level was set at 5%.

Results

One-way ANOVA showed that the type of the measuring tool had a highly significant effect ($P < 0.05$) on the measured distances in the samples, leading to the rejection of the null hypothesis (Table 1). The means of the measured distances were comparable between the M group and V group with larger values for the X group

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and lower values for the V group (Figure 5). The Tukey's HSD showed no significant difference between M and X groups as well as M and V groups in RI-LI distance (P = 0.109 and 0.699 respectively). The only difference has existed only between the X group and the V group regarding the previously mentioned measured distance (P = 0.02). While the mean value of the rest of the measured distances showed no differences between the M group and the V group (P > 0.05), a highly significant difference exists between the means of group M vs X and group X vs V (P < 0.05) respectively.

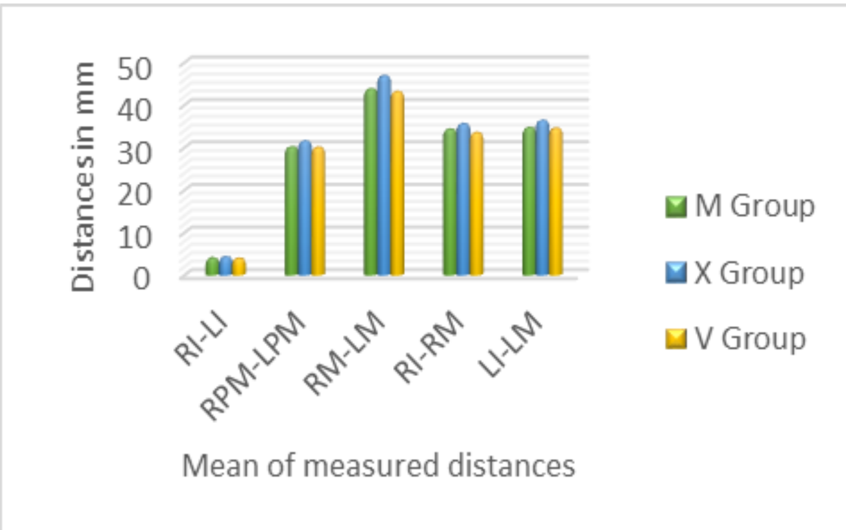

FIGURE 5. Bar chart showing and compare the means of the measured distances between studied groups.

Table 1. Means and standard deviations (SDs) of distance values between each measurement points.

Measured distances (mm)	M group		X group		V group		P-value*
	Mean	SD	Mean	SD	Mean	SD	
RI-LI	4.114	0.207	4.352	0.302	4.024	0.246	0.021
RPM-LPM	30.222	0.171	31.580	1.564	30.106	0.256	0.002
RM-LM	43.836	0.503	46.936	1.262	43.202	0.538	0.000
RI-RM	34.398	1.358	35.667	0.229	33.546	0.205	0.000
LI-LM	34.752	0.983	36.438	0.529	34.608	0.366	0.000

**Significant difference at 0.05 level.*

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Discussion

In the construction of complete dentures and most of dental restorations, the dimensional accuracy is the most important issue for better adaptation and clinical outcome. Shrinkage or expansion had been inevitable for most of dental materials and for that reason many studies [4–7,11,17,21–23] had been conducted to evaluate the causes and obtain the best possible scenarios for the manufacturing of complete dentures and dental restorations to ensure better stability and clinical results. In the present study, there was a statistical significant difference between the types of measuring devices used on measuring the linear distances in denture base samples, leading to the rejection of null hypothesis.

The distances which had been measured with CAD CAM software (Group X) showed larger means with significant difference with those of group V and M respectively. This could be explained as the linear measurements showed a high positive correlation with the rate of image magnification as explained by Rino Neto et al [24]. Using the CAD CAM software, the metal millimeter calibration ruler had been used for calibration as it is an accurate reference for linear measurements magnification correlation [25], as the CAD CAM software was able to magnify the reference points for 10 times or more and because it had been made from amalgam, the margin had been distorted making it so difficult to locate the boundaries of the reference points when compared to the visual acuity of the measuring microscope and its ability to sharply identify the margins of the reference points without distortion. Image distortion could be influenced by misalignment between the x-ray source, the cephalostat, the film, and the object [26], but in the present study, the samples has been placed in a custom-made handle that maintain the distances and eliminating the misalignment of the previously mentioned parts within the x ray unite. Furthermore, image distortion could also be influenced by x-ray beam geometry. After originating from the x-ray source in the tube, the x-ray beam travels in a divergent pattern with the field size limited by a collimator consisting of adjustable lead attenuators or shutter. The collimator and shutter control the size of the x-ray beam by absorbing peripheral x-rays [25]. This limitation by itself could be responsible for the differences in reading the distances especially when measuring large distances (Table 1). RI-LI distance showed no significant difference between the studied groups, the only difference exists between group V and group X which could be explained by the lack of visual acuity and magnification with the Vernier caliper given smaller distances. All other measured distances showed highly significant differences between the studied groups as explained previously.

The measurements of all distances in group M and V are close to each other with no statistical significant difference. All the measured distances in the V group show lower values compared to the M group. The Vernier caliper is an excellent tool for measurement and had been used for decades in studies involving dimensional stability or accuracy [9,22,27], but making measurements with zero errors is a challenging task with Vernier caliper due to difficulty of identifying exactly what to focus on during identifying boundaries of the reference lines and how much length to compensate for [28]. This explain the smaller values for the V group compared to the M group in which the reference points had been magnified with sharp identification of the boundaries of

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the reference point and higher accuracy than is possible with bare eyes which is a characteristic feature of the measuring microscope.

Limitation of this study includes not involving any digital photography or STL files of CAD CAM scanner and comparing them to the conventional measuring tools like Vernier caliper and / or measuring microscope.

Conclusion

The Vernier caliper gives more accurate reading than the AutoCAD soft-ware combined with radiographs when both compared to measuring microscope.

Conflicts of interest

The authors have no conflicts of interest to declare.

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