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Comparison of Retention between Milled and Conventional Denture Bases: A Clinical Study

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Comparison of Retention between Milled and Conventional Denture Bases: A Clinical Study

by

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A Thesis submitted in partial satisfaction of
the requirements for the degree
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Each person whose signature appears below certifies that this thesis in his/her opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

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DEDICATION

This project is dedicated to my program director Dr. Mathew Kattadiyil who have been my constant source of inspiration and motivation, my research committee Dr. Nadim Baba and Dr. Charles Goodacre for their guidance, my parents and wife for being supportive during the hard times. Without their love and support this project would not have been made possible.

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ABBREVIATIONS

CD	Complete Denture
PMMA	Poly(methyl methacrylate)
CNC	Computer Numeric Control
CAD/CAM	Computer Aided Design-Computer Aided Manufacturing
DAFG	Digital Advanced Force Gauge
FTD	Force Transmission Device
STL	Surface Tessellation Language
lbs	Pounds
GDS	Global Dental Science

ABSTRACT OF THE THESIS

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by

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Master of Science, Graduate Program in Prosthodontics
Loma Linda University, March 2016
Dr. Mathew Kattadiyil, Chairperson

The advancement in dental material technology led to the improvement in the fabrication method of PMMA denture bases. Denture base adaptation can be influenced by the amount of polymerization shrinkage that occurs during the processing method of fabrication. CAD/CAM dentures milled from prepolymerized PMMA acrylic resin blocks theoretically have reduced or no polymerization shrinkage. There have been no clinical studies, to date, that have compared retention values between milled and conventionally processed denture bases. Therefore, the purpose of this study clinical study was to compare the retention values between conventional heat polymerized and digital milled maxillary denture bases.

Twenty patients (n=20) with completely edentulous maxillary arches participated in this study. At the first visit, a preliminary impression was made and poured in type III dental stone. A custom tray was constructed from Triad light cure material. At the second visit a heavy body PVS impression material was used to border mold the trays and a final impression was made with light body PVS impression material. The final impression was scanned and the STL files were sent to Global Dental Science for the fabrication of a

CAD/CAM milled denture base (AvaDent) (group A). Then the final PVS impression was poured in type III dental stone. The master cast was used to fabricate a heat polymerized acrylic denture base resin (group B). A unique testing device was used to measure denture retention in lbs. The testing device was composed of three parts; DAFG (attached to a motorized test stand), customized FTD and a Panadent earbow (modified and mounted to a customized wooden stand). The FTD consisted of a hollow brass rod with a pulley at each end used to transfer the force through a nylon thread. A snap hook attachment was attached to the denture base at the center with autopolymerizing resin. The nylon thread was tied securely to the snap hook. At the other end the nylon thread was attached to the DAFG through a secure grip attachment. Each denture base was subjected to a vertical pulling force three times at 10-minute intervals.

The statistical analysis showed significant (α>.05) increase in retention for milled denture base method of fabrication over the conventional polymerizing method with a mean (N) difference of 4.47 lbs (P<0.001). Average retention for the milled denture bases was 16.66 ± 7.32 lbs and average retention for the conventional heat polymerized denture bases was 12.19 ± 6.15 lbs.

Based on analysis of results, it was concluded that the retention of digitally designed and milled complete denture bases from prepolymerized PMMA acrylic resin blocks offer significantly higher retention than the denture bases fabricated by a conventional heat polymerized method.

CHAPTER ONE

INTRODUCTION

Several materials have been used over the years for the fabrication of removable complete dentures (CD). Bone, wood, ivory, porcelain, metals and polymers have been utilized for the fabrication of CDs with Poly(methyl methacrylate) (PMMA) being the most widely used.[1-3]

The advancement in dental material technology led to the improvement in the fabrication method of PMMA denture bases. Various methods are available for the fabrication of PMMA CD bases using heat, auto, light, microwave polymerization, rapid prototyping or computer numeric control (CNC) milling.[2,4-6]

Factors for Successful Complete Denture

Jacobson and Krol[7-9] reported that the fabrication of a successful CD requires satisfactory stability, support and retention. Retentive factors have been explored, and their influence in successful CD therapy have been proven.[10-16] Several methods and devices have been used in previous studies to measure the retention for different types of denture bases. In addition, effect of posterior palatal seal design, palatal tissue surface design with or without relief, denture base surface enhancement with air particle abrasion and adhesives in improving CD retention have been reported.[17-25] The achievement of a superior adaptation and maximum achievable coverage of the denture base, has also been proven to be an important retention factor.[26]

Digital Milled Dentures

Computer Aided Design-Computer Aided Manufacturing (CAD/CAM) with CNC as a link between CAD and CAM evolved a new era for clinical dentistry.[5] The application of CAD/CAM technology in fixed prosthodontics and implant dentistry led to its application in removable prosthodontics. Several advantages of CAD/CAM or digital complete dentures have been reported in the literature.[4,5,27-29] These are; reduced clinical chair time (two-visit appointment) for the denture fabrication and placement; ability to duplicate a replacement or a spare prosthesis using the digital data stored by the manufacturer; high strength and density; reduced cost and lack of polymerization shrinkage of the acrylic resin.[4,5,27-29]

One example, fabrication of the AvaDent Digital Dentures (GDS) involves scanning of the intaglio and cameo surfaces of the final impressions and records. The resulting information is digitally processed to enable virtual designing of the dentures. The information is then exported to a CNC milling machine to fabricate the final denture base[28], or the actual denture from a prepolymerized acrylic resin block.[4] The denture teeth are then attached to the recesses on the denture base.[4-5]

Poly(methyl methacrylate) Properties

Denture base adaptation can be influenced by the amount of polymerization shrinkage that occurs during the processing method of fabrication.[30-35] Recently research reports have proven that dimensional changes in denture bases due to polymerization shrinkage affect their adaptation in two ways namely;denture base expansion and contraction. Polymerization shrinkage in heat polymerized PMMA denture bases occurs in all directions (referred as “twisting” of the denture base), with a linear shrinkage less than 1% (0.5 mm) and a volumetric shrinkage of 7%.[30-35]

PMMA denture base also expands in a hydrated environment, linear expansion accounts for 0.23% for each 1% increase in weight.[3] This expansion may counter the influence of polymerization shrinkage, depending on the amount of residual monomer.

Statement of the Problem

The advancement in dental material technology has resulted in improvement in the methods of fabrication for PMMA denture bases. Polymerization shrinkage of denture bases during processing has been known to influence its adaptation over the edentulous arches. The adaptation of digital milled dentures, from prepolymerized PMMA acrylic resin blocks, theoretically should be superior to the conventional heat polymerization method. There have been no clinical studies, up to date, that have determined and compared retention values between milled and conventionally processed denture bases. Therefore, the purpose of this clinical study was conducted using a unique methodology to compare the retention values between conventional heat polymerized and digital milled maxillary denture bases.

The null hypothesis for this study was that there would be no difference in retention between maxillary digitally milled and conventional heat polymerized denture bases.

CHAPTER TWO

MATERIALS AND METHODS

Sample and Inclusion Criteria

Approval was obtained from the Institutional Review Board of Loma Linda University before conducting this study. Twenty complete maxillary edentulous patients (11 men and 9 women, average 68 years of age) signed informed consents before participating in this study. For the inclusion criteria, patients needed to be of legal age (above 18 years of age) to provide consent and should have had been completely edentulous in the maxillary arch for a minimum period of 1 year. Exclusion criteria included presence of ridge and soft tissue pathology, reduced salivary flow, history of taking medication that would alter the quantity and quality of saliva, presence of severe ridge undercuts and palatal torus/tori that required surgical correction.

Each edentulous maxillary arch type was classified according to McGarry et al[36] observing their criteria regarding the vestibular depth, ridge morphology, maxillary tuberosity, hamular notches and presence of tori and or exostoses Table. 1.

Table 1. List of subjects included in the study and their characteristics.

Subject Characteristics			
Average Age	68.20 ± 7.27 years		
Gender	Male	11	55%
	Female	9	45%
Race	White	13	65%
	Hispanic	3	15%
	African American	2	10%
	Hawaiian	2	10%
Arch form	Round	8	40%
	Square	8	40%
	Tapered	4	20%
Maxilla Type	A	9	45%
	B	7	35%
	C	4	20%
House palatal throat form	I	7	35%
	II	7	35%
	III	6	30%

Total sample size was 20 patients.

According to McGarry et al[36], Type A maxilla is featured with high anterior and posterior vestibular depth, palatal morphology, tuberosities and well defined hamular notches that resist vertical and horizontal denture movement. Type B maxilla has poorly defined tuberosities and hamular notches, no buccal (posterior) vestibule, yet palatal vault morphology resists vertical and horizontal movement. Maxilla with loss of anterior vestibule and present with palatal vault morphology that offer minimal resistance to vertical and horizontal forces are classified as Type C. However, in the absence of both anterior and posterior buccal vestibule, presence of prominent anterior nasal spine and palatal vault morphology that does not resist denture movement is considered as Type D.

The maxillary arch form was classified and recorded based on House classification Table. 1.[37] The maxillary arch form was classified as round, square or tapered.

Final Impression Making

At the first visit, a preliminary impression was made using an irreversible hydrocolloid impression material (Alginate Jeltrate Regular Set, Dentsply). The preliminary impression was poured according to manufacturer instructions with type III dental stone (Golden, WhipMix Corporation). Custom trays were constructed using Triad light cure material (Tru Tray Sheet, Dentsply). The custom trays were trimmed to be 2 mm shorter than the vestibular sulcus to allow for border molding.

For the second visit, patients were instructed not to wear their complete denture 24 hours prior to the appointment. A heavy body poly(vinyl siloxane) (PVS) impression material (Aquasil, Dentsply) was used to border mold the trays and a final impression was made with a light body PVS impression material (Aquasil, Dentsply). The posterior palatal seal area was delineated on the maxillary impression using a protocol outlined by Hardy and Kapur.[16] Melted Korecta wax (Kerr Corporation) was used on the definitive impression and reseated on the patient's edentulous maxilla to capture the final design and form of the posterior palatal seal. Any excess wax was then carved away and removed as illustrated in Figure. 1A and B.

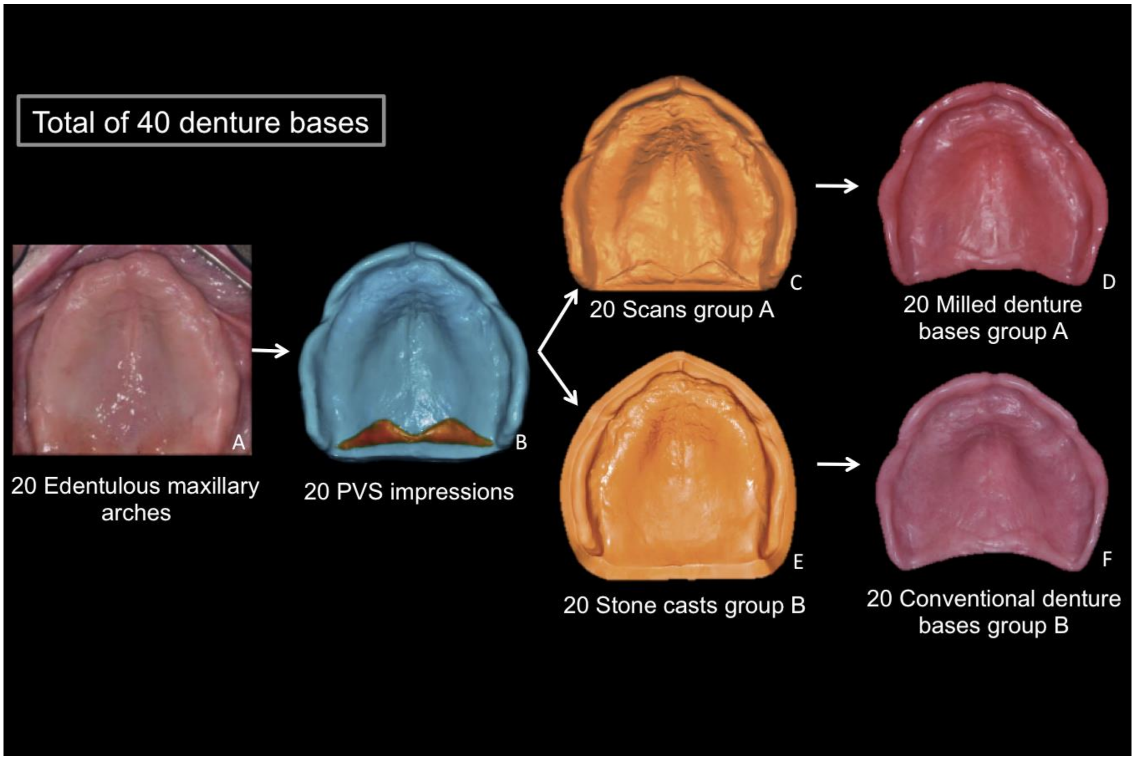

Figure 1. Illustrating the study design and groups. a. Maxillary edentulous arch, b. PVS impression material with the final form of the posterior palatal seal, c. a scan of the maxillary final PVS impression, d. milled maxillary AvaDent denture base, e. master stone cast, and f. conventional heat polymerized denture base.

Denture Bases Fabrication

The definitive impression was scanned (iSeries; Dental Wings) within 24 hours to virtually capture the impression details as illustrated in Figure. 1C. The STL file of the scanned maxillary impression was sent to Global Dental Science, LLC (GDS) for the fabrication of the milled denture bases (AvaDent) (group A) as shown in Figure. 1D. Following scanning, the impression was poured in type III dental stone (Golden, WhipMix Corporation) to fabricate a master cast as shown in Figure. 1E. The master cast was used to fabricate a heat polymerized acrylic denture base resin (Lucitone 199, Dentspy) (group B) shown in Figure. 1F. The conventional heat polymerized denture bases were processed under a long polymerization cycle, 9 hours in a water bath at 73^{o}C ±1^{o}C followed by 1/2 hour in boiling water as recommended by the manufacturer.

Testing Apparatus component

The testing device composed of three parts:

Digital advanced force gauge (DAFG)

Consists of a Mark-10 series-4 force gauge (Mark-10 Corporation), which was used to read the force required to dislodge each denture base from the edentulous ridge. The DAFG is a part of the Mark-10 extended length ESM301L motorized test stand (Mark-10 Corporation), which was set at a crosshead speed of two inches/minute, allowing standardization of the pulling speed in all the subjects as illustrated in Figure. 2A and B.

Figure 2. Illustrating testing apparatus. A. DAFG, B. motorized test stand Mark-10 extended length ESM301L, C. wood stand, D. FTD, E. grip attachment, and F. Panadent earbow.

The measurement of retention was recorded in pounds (lbs). The motorized testing device was attached to the clinical bench by a mounting wood stand, to enable the collection of data while the patient sits in an upright position shown in Figure. 2C.

Force Transmission Device (FTD)

This consists of a hollow brass rod made from a customized autoclavable aluminum alloy with one pulley at each end used to transfer the force horizontally through a disposable nylon thread (Braided Dacron, Tuf-Line) as demonstrated in Figure. 2D and 3. A snap hook attachment already centered on the denture base was then connected to the nylon thread with the FTD oriented straight below the hook attachment resulting in a vertical force delivery. The other end of the nylon thread was attached to the DAFG through a grip attachment placed in a direct line above the FTD again confirming a vertical force delivery as demonstrated Figure. 2E.

The vertical adjustment was obtained by moving the patient's chair up and down while the horizontal adjustment was obtained through the FTD. The horizontal adjustment was done through the adjustment of 4 knobs designed in the FTD shown in Figure. 3A.

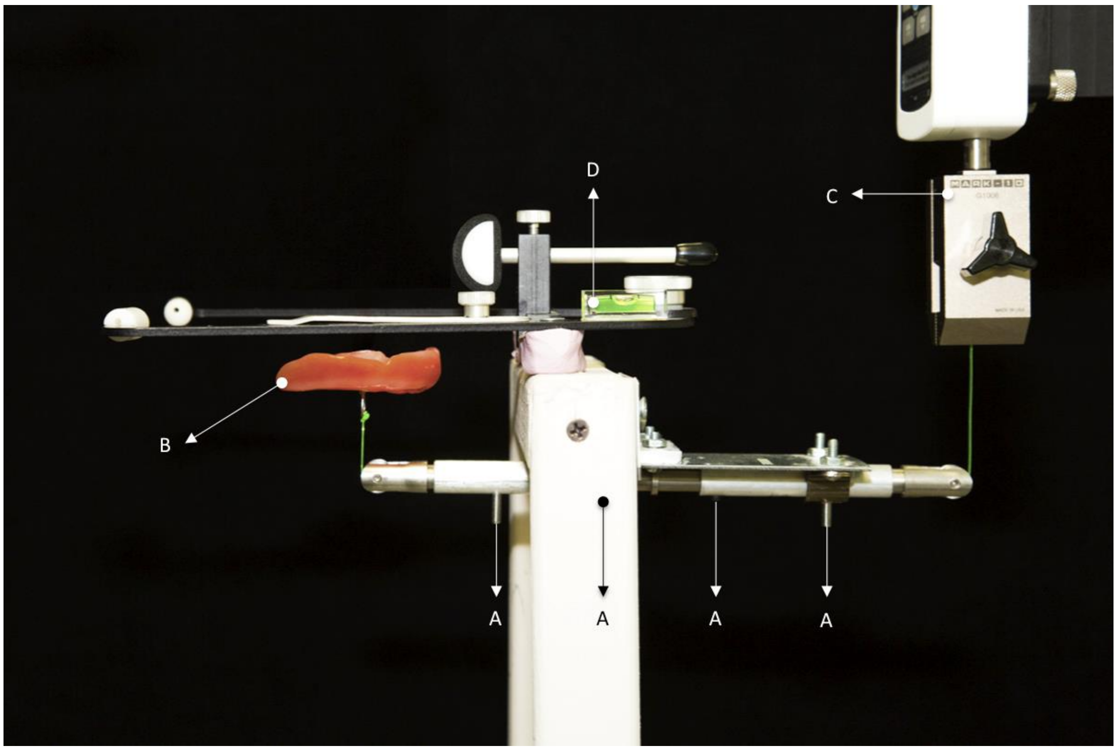

Figure 3. Illustrating the FTD. A. 4 adjustment knops for horizontal distance orientation, B. denture base subjected to vertical dislodgment force, C. attachment grip exerting a pulling vertical dislodgment force, and D. bubble gauge confirming a parallel aliment of the Panadent earbow and FTD to the floor.

This adjustment allowed placement of the end of the FTD directly in a straight line below the center of the denture base where the snap hook had been attached.

This adjustment ensured a vertical pulling force that was oriented perpendicular to the horizontal plane shown in Figure. 3B and C. This was a critical part of the test assembly as in a pulley system like this; the input force would equal the output force only if the force delivery is vertical. The FTD was autoclaved and the nylon thread replaced after being used for testing on each subject.

Panadent Earbow

An earbow (Panadent Corporation) was modified and mounted to the mounting stand perpendicular to the floor, orienting and stabilizing the patient's head to the Frankfort horizontal plane to calibrate and direct the dislodgment forces in a vertical direction. The ear bow was oriented parallel to the horizontal plane using a bubble gauge shown in Figure. 2F and 3D.

Locating the Center of Denture Bases

The center of the denture base on the obtained maxillary master cast was located by marking the center of the labial frenum (point A), and pterygomaxillary fissures (point B and C). The half distance between points B and C was marked as the mid-posterior border of the denture base (point D). Finally half the distance between point A and D was marked as the center of the denture base (point E) as illustrated in Figure 4.

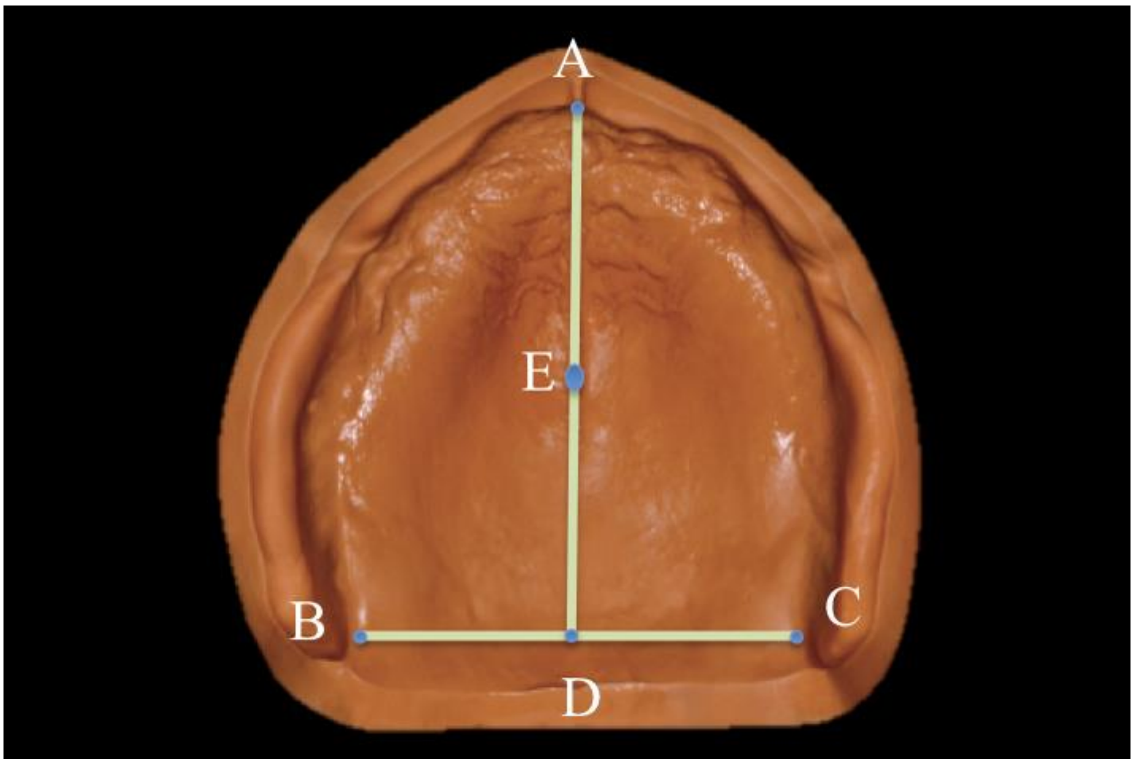

Figure 4. Method used in locating the center of the cast. a. Center of the labial frenum, b and c. pterygomaxillary fissures, d. mid-posterior border of the denture base and finally e. the center of the denture base.

Testing Procedure

Each patient was instructed not to wear any type of prosthesis in the maxillary arch for 24 hours prior to the testing appointment. Each denture base was stored in water immediately after fabrication and remained soaked until the test was performed. Each denture base was inspected and seated intraorally. The denture base adjustment and confirmed fit were made using pressure indicator paste (Henry Schein) to detect and relieve areas of impingement. Patient response regarding comfort, when wearing the test denture bases was also noted. A stainless steel snap hook attachment with standardized weight and dimensions was fixed in the center of each denture base with autopolymerizing acrylic resin for 10 minutes at 15 psi pressure in 43°C (warm)water according to manufacturer instructions (Lucitone 199® Repair Material, Dentsply) as shown in Figure. 5.

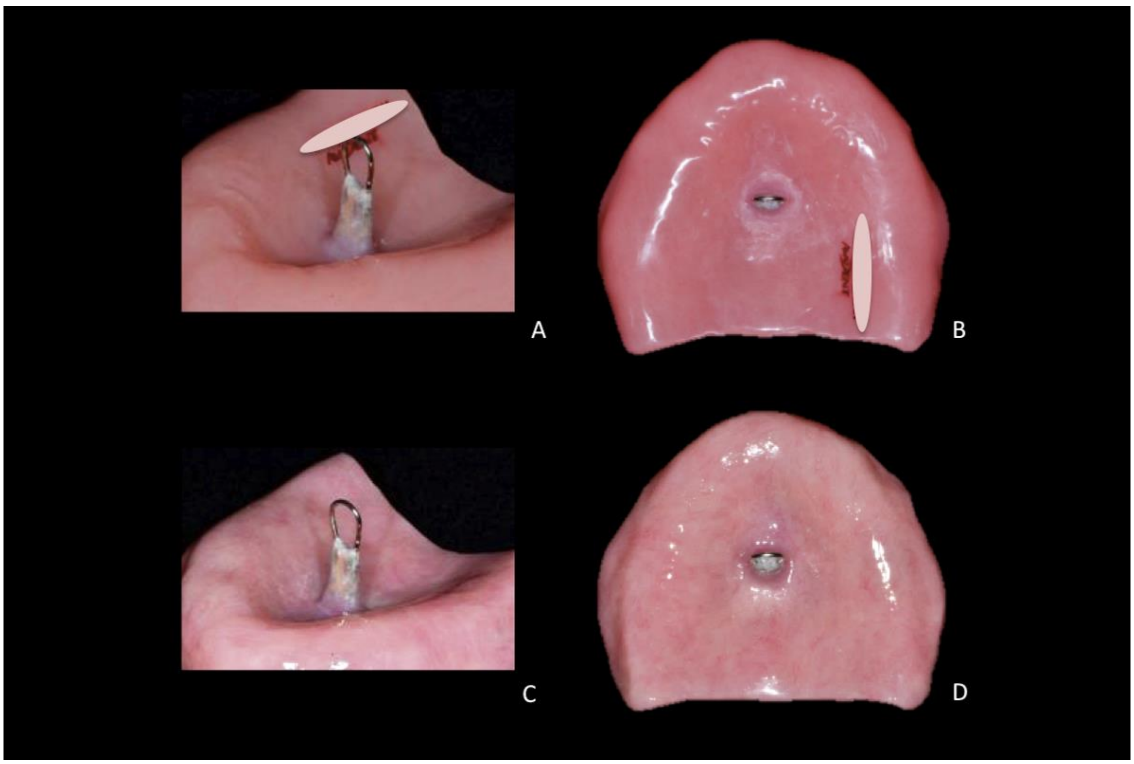

Figure 5. Showing stainless steel hook attached to the denture bases A and B. as an example of the milled denture base group A, C and D. as an example of the conventional heat polymerized group.

Each denture base was firmly seated over the edentulous maxillary arch for five minutes before testing started. The nylon thread attached to the snap hook and the denture base was then subjected to a vertical pulling force using the testing assembly. This procedure was repeated three times at 10 minute intervals for each denture base and each retentive value was recorded in lbs. The testing procedure was performed alternating between the 2 groups (group A and group B) through the study.

Statistical Analysis

ANOVA measurements procedure was used to compare average retention between group A and B using level of significance $\alpha=0.05$. All statistical analyses were performed using IBM SPSS Statistics (Version 20; IBM Corporation 1989, 2011).

CHAPTER THREE

RESULTS

The subject characteristics of 20 subjects (11 men and 9 women) with an average age of 68.20 ± 7.27 years are shown in (Table. 1). The average values for retention between the two methods of fabrication for denture bases group A (milled bases) and B (conventionally heat polymerized bases) are illustrated in Figure. 6.

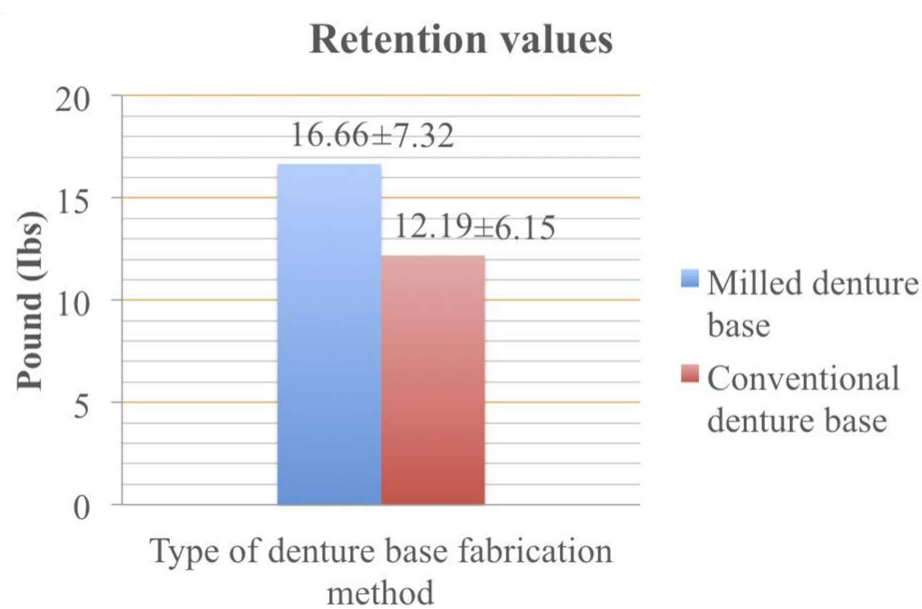

Figure 6. Bar chart comparing the retention values outcome of Milled and Conventionally heat polymerized denture bases.

The statistical analysis showed significant increase in retention for milled denture bases over the conventionally heat polymerized denture bases with a mean difference of 4.47 lbs ($P<0.001$). Average retention for the milled denture bases was 16.66 ± 7.32 lbs and average retention for the conventional heat polymerized denture bases was 12.19 ±

6.15 lbs.

A stratified analysis to compare between conventional and milled denture bases by arch form was conducted. No significance was found among different type of arch form for round, square and tapered and denture base method of fabrication. However, higher retention was found with the tapered arch form regardless of the fabrication method of denture base ($P<0.094$) as illustrated in Figure. 7.

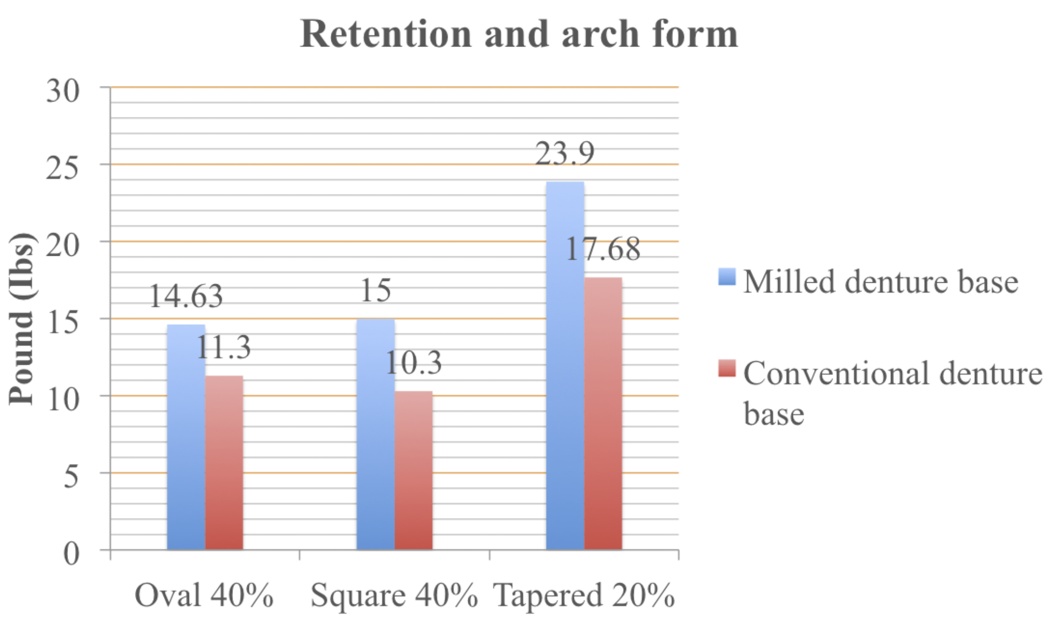

Figure 7. Bar chart comparing the retention values outcome of different arch Forms in relation to the denture base type.

Another stratified analysis was performed to compare conventionally heat polymerized and milled denture bases by maxilla types. None of the sample subjects presented with a maxilla Type D. No significant difference in retention was found among maxilla Types A, B and C. However, higher retention was found with maxilla Type A for both denture base groups, A and B (P<0.086) as illustrated in Figure. 8.

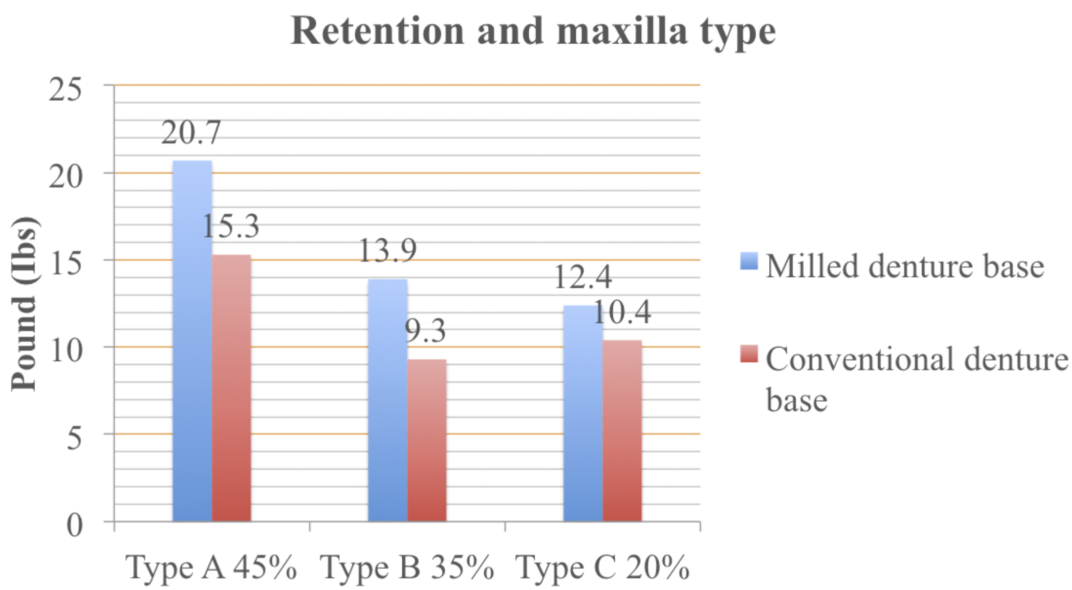

Figure 8. Bar chart comparing the retention values outcome of different arch Types in relation to the denture base type.

CHAPTER FOUR

DISCUSSION

The null hypothesis that there would be no difference in retention between maxillary digitally milled and conventional heat polymerized processed denture bases was rejected. Multiple explanations for this can be offered.

Retention Outcome of Denture Base

Superior retention with milled CDs have been mentioned in previous reports as a possible advantage of digital dentures.[4,28,] Kattadiyil et al2[8] reported significantly higher retention for digital dentures compared to conventional completed dentures. Their study was conducted in a predoctoral setting where each patient received a set of digital CD and conventionally fabricated CD. Faculty evaluation determined significantly higher retention, fit, stability and superior denture base contour. A patient questionnaire was also given to each patient after wearing both dentures, each denture for a week. Patient satisfaction with digital CDs was significantly higher than conventionally processed CDs in terms of comfort, retention, chewing efficiency, prostheses selection and efficiency of technique.

The methodology used to assess retention by Kattadiyil et al[28] was a clinical examination by faculty and biofeedback from patients using a Likert scale of measurement. However, in our study, we used a unique testing device to determine denture base retention that was calibrated to perform force measurements similar to an Instron machine but was easily portable for intraoral clinical measurements. Despite the difference in methodology, our results also revealed significantly higher retention for maxillary digital denture bases. This is most likely due to the lack of polymerization shrinkage associated with milled denture bases which results in an improved fit, thereby improving retention.[4,5,28]

PMMA shrinkage can cause denture distortion due to volumetric and linear polymerization shrinkage.[3,30-35] Traditionally this has been countered by hydrating the denture bases in water and we used this protocol in our study for both denture bases.[3] This expansion due to hydration may counter the influence of polymerization shrinkage, depending on the amount of residual monomer.[3] In our study each denture base was stored in water immediately after its fabrication, yet the clinical result showed significant increase in retention for the prepolymerized group. One explanation for this could be the increased density of the milled denture bases as they are fabricated from a dense block of prepolymerized acrylic resin, which might not have been influenced by hydration. This could be a potential variable to study in the future.

Denture Base Retention and Maxilla Type

As exclusion criteria in our study, the presence of palatal tori or bony exostoses requiring surgical correction had been eliminated from the study. This allowed us to objectively evaluate the difference in retention if any, between the types of maxilla in our study. Despite the difference in clinical features between maxilla Type B and C, they had a very similar outcome in retention. However, a noticeable increase of retention among maxilla Type A was recorded compared to the other two types. This could be explained by the increased surface area, which might be found in maxillary Type A, which could then improve retention.

Denture Base Retention and Maxilla Form

The tapered arch form is associated with a deep palatal vault.[35] Denture bases conventionally fabricated for a maxillary edentulous arch with such a feature is believed to have more denture distortion during processing. Hence, a reduction in retention is anticipated and has been reported. However, our findings showed a noticeable increase in retention with the tapered arch form group. The limited sample size (4 subjects) precludes any objective conclusions other than to recommend further study utilizing a large sample size.

Methods of Measuring Denture Retention: Review of Literature

Multiple methods and devices have been proposed in the literature to measure the amount of retentive force to dislodge a denture base intraorally.[17-25] These included a variety of devices that used either a pulley system with a weighing pan, spring balance device, spring gauge, spring scale, strain gauge force transducer, retentiometer, dynamometer or a gnathometer. [17-25] However, none of the used devices or methods were designed to deliver the dislodgment forces in a true vertical direction or were standardized to deliver the dislodgment force in a constant speed which is critical in a pulley system.[17-25]

Study Unique Testing Apparatus

The unique complex testing apparatus used in this study was created by assembling a digital DAFG with a motorized testing stand which was mounted securely to a wood stand. The motorized test stand standardized the dislodgement force subjected on to each maxillary edentulous arch with a constant crosshead speed set at 2 inches per minute. An earbow was used to orient the patient head and standardize the vertical dislodgment force applied to the subjects. Use of the FTD allowed the application of dislodgment forces exerted on the maxillary arches in a true vertical direction.

This study is the first to direct standardized vertical dislodgment forces using a unique testing device to the maxillary edentulous arch to measure retention values for denture bases when compared to previous studies.

Study Limitations

Another limitation to this study was that patients were tested at ten minute intervals instead of a longer period for patient convenience. This interval of time might not be sufficient for soft tissues to re-conform to its original shape and hence could have affected outcome. However no significant variations (standard deviations) were seen for the 10 minute intervals.

This clinical study attempted to objectively assess if there was a difference in retention between conventional heat polymerized and digital milled denture bases, and succeeded in doing so. The testing device assembled for dislodgement force measurement have not bee used before to the best of the author's knowledge.

The findings from this study should encourage discussion regarding evaluating retention values for the mandibular arch but unfavorable surface areas, difficulty in centralizing forces due to the presence of the tongue, all contribute to study complexity but offers scope for innovative study in the future.

Conclusions

Within the limitations of this clinical study the following conclusions can be drawn:

1. The retention of digitally designed and milled complete denture bases from a prepolymerized PMMA acrylic resin blocks had significantly higher retention than the conventional heat polymerized method of denture base fabrication.
2. The choice of a milled denture base might be appropriate when decreased retention for the maxillary arch is expected in a clinical situation.
3. Maxillary arch form and type did not seem to influence retention for both types of denture bases.

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