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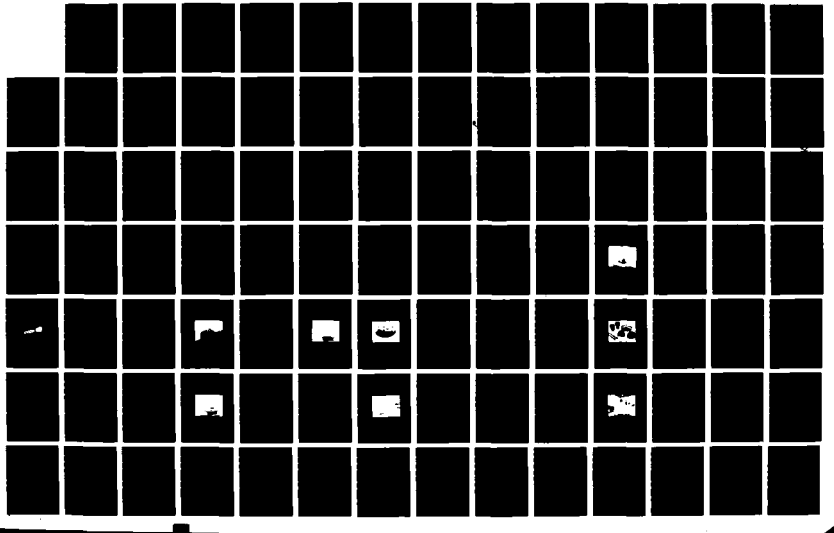

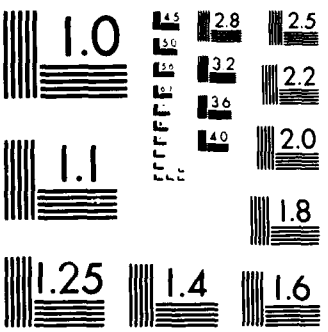

THE EFFECTS OF FABRICATION TECHNIQUES AND STORAGE METHODS ON THE DIMENSIONAL STABILITY OF REMOVABLE ACRYLIC RESIN ORTHOSES

A

THESIS

Presented to the Faculty of

The University of Texas Graduate School of Biomedical Sciences

at San Antonio

in Partial Fullfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

By

David Mark Bohnenkamp, B.S., D.D.S.

San Antonio, Texas

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THE EFFECTS OF FABRICATION TECHNIQUES AND STORAGE METHODS ON THE DIMENSIONAL STABILITY OF REMOVABLE ACRYLIC RESIN ORTHOSES

David M. Bohnenkamp, Major, DC, USAF

Several empirical claims appear in the literature for improved dimensional stability when utilizing a particular fabrication technique for interocclusal orthopedic stabilization appliances. The primary objective of this study was to utilize five specific fabrication techniques and two storage methods to construct and store acrylic resin specimens, and to visualize and quantify their linear dimensional change over a two week time period. An original research model was developed to approximate more closely the tooth coverage limits of removable acrylic resin orthoses. Four pindex pins were transferred to each individual specimen and measurements were made of the distances between the inside diameters of the pins. Ten specimens were fabricated on individual die stone casts for each of the five techniques. After construction, initial measurement, and removal from their cast, each specimen was stored in either a wet or dry environment for the duration of the study. Measurements between pins were made and recorded at five time intervals. No significant difference in dimensional change was noted between the one-stage and three-stage segmental sprinkle-on autopolymerizing acrylic resin fabrication techniques. The one stage sprinkle on technique resulted in less dimensional change than the dough application, vacuum adapted resin sheet and dough application, and heat cured denture processing techniques. Specimens stored in a wet condition showed less distortion after two weeks.

THE EFFECTS OF FABRICATION TECHNIQUES AND STORAGE METHODS ON THE DIMENSIONAL STABILITY OF REMOVABLE ACRYLIC RESIN ORTHOSES

David Mark Bohnenkamp

APPROVED:

Supervising Professor

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DEDICATION

I want to dedicate this Thesis to the three people who have made this all possible.

First to my parents, Robert and Peggy Bohnenkamp who have always provided encouragement and emotional support. They have been supportive of all my endeavors in life, but especially of this one. I want to thank my Mom and Dad for helping make so many things possible.

To my loving friend, Lily Garcia, this Thesis is dedicated. She has always encouraged me to do my very best and take that extra step. She has given me tremendous emotional support throughout my entire prosthodontics graduate degree program, but especially during the writing of this Thesis.

I want to express my sincere thanks and dedicate this Thesis to my parents and my friend.

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THE EFFECTS OF FABRICATION TECHNIQUES AND STORAGE METHODS ON THE DIMENSIONAL STABILITY OF REMOVABLE ACRYLIC RESIN ORTHOSES

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Numerous articles and chapters have been written describing various construction methods for interocclusal stabilization appliances (orthoses). A review of this literature revealed several claims for improved dimensional stability when utilizing a particular fabrication technique. An investigation of the dimensional stability of various construction techniques, or of the empirical claims as to the advantages of a given technique, does not appear in the literature.

The purpose of this study was to design and conduct an experiment to determine if fabrication techniques and storage methods affect the dimensional stability of removable acrylic

resin orthoses. The primary objective of this investigation was to utilize five fabrication techniques and two storage methods (representative of those in the literature) to construct and store acrylic resin specimens, and to visualize and quantify their linear dimensional change with a measuring microscope.

A computer designed and machined master aluminum die was fabricated to serve as an original research model for this investigation. The aluminum die was constructed to approximate more closely the tooth-coverage limits of removable acrylic resin orthoses. Pindex pins were placed parallel to each other at the canine and second molar areas of the research die. The locations of the pins were designated A, B, C, and D. Fifty improved dental stone research casts were made of the master aluminum model. The locations of the pins were transferred to each research cast.

Five specific fabrication techniques, designated A, B, C, D, and E, were utilized to construct 50 acrylic resin specimens. Ten specimens were fabricated on individual die-stone casts for each of the five fabrication techniques. The design of each specimen ensured coverage of the lingual and occlusal surfaces (approximately 3 mm thick) and 3 mm of the buccal surfaces of the research cast arch form. Design A consisted of a one-stage sprinkle-on autopolymerizing acrylic resin technique. Design B consisted of a three-stage segmental sprinkle-on autopolymerizing acrylic resin technique. Design C consisted of autopolymerizing acrylic resin dough application technique. Design D consisted of

a vacuum-adapted resin sheet and autopolymerizing acrylic resin dough application technique. Design E consisted of a heat-cured acrylic resin denture processing technique.

After construction, initial measurement, and removal from their individual die-stone research cast, each specimen was stored in either a wet or dry environment for the duration of the study. Fifty percent of the available specimens from each design group were selected and stored in water in a zip-lock bag at room temperature. The remaining specimens were stored in air in a zip-lock bag at room temperature.

As a method to determine the dimensional stability of the specimens, the distances between the inside diameters of the four pins were measured with a measuring microscope. These distances were designated A-B, C-D, A-C, and B-D, and respectively represented anterior, posterior, left, and right dimensions of the casts and specimens. Baseline measurements were made between the pins and recorded at the following time periods: Initial Measurement, on die-stone research cast; On Cast, after fabrication of specimen; 0 Hours, specimen off cast; 24 Hours, specimen stored wet or dry; 72 Hours, specimen stored wet or dry; and Two Weeks, specimen stored wet or dry. Cumulative linear dimensional change was calculated by subtracting the initial measurement from the measurement at each time period.

The following results and conclusions can be drawn from statistical analysis and evaluation of mean cumulative linear

dimensional change across design, storage condition, location, and time:

1. No significant difference in linear dimensional change was noted between the one-stage and the three-stage sprinkle-on fabrication techniques at any of the locations at any of the time periods ($p < .05$).
2. This result suggests that the incorporation of three stages in a sprinkle-on technique for autopolymerizing acrylic resin does not seem to offer any advantages in terms of minimizing linear dimensional change when compared to a one-stage sprinkle-on technique.
3. The one-stage sprinkle-on technique (Design A) demonstrated significantly less dimensional change than the dough application (Design C), the vacuum-adapted resin sheet and dough application (Design D), and the heat-cured denture processing (Design E) techniques at location C-D for all five time periods ($p < .05$), except for Design E at Time 1 (On Cast minus Initial Measurement).
4. The heat-cured acrylic resin denture processing technique (Design E) demonstrated significantly less dimensional change than the vacuum-adapted resin sheet and dough application technique (Design D) at the posterior location C-D at all time periods ($p < .05$), except at Time 2 (24 Hour minus Initial Measurement).

5. All specimens stored in a wet environment demonstrated significantly less linear dimensional change two weeks after fabrication than specimens stored in a dry environment ($p < .05$).
6. These results suggest the laboratory utilization of an autopolymerizing acrylic resin sprinkle-on fabrication technique and a wet storage method to minimize linear dimensional change prior to the clinical use of a removable acrylic resin orthosis.

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I. INTRODUCTION

No treatment for dental disease has been characterized by more variety of concept and technique than that of interocclusal stabilization appliance therapy. Numerous articles and chapters have been written describing various construction methods for these orthotic appliances. A review of this literature reveals several unsubstantiated claims for a more accurate and precise fit when utiliizing a particular fabrication technique.

Because the success of an "oral orthosis" (47) depends on how well it fits, dimensional stability during the construction process is critical. It is reasonable to assume that a construction technique should exist for removable acrylic resin orthoses which can minimize distortion, eliminate mechanical stress, improve strength, and provide for a precise fit. It is suprising, however, to find that an investigation of various construction techniques, or empirical claims as to the advantages of a given technique, does not appear in the literature as of today.

The purpose of this study is to design and conduct an experiment to determine if fabrication techniques and storage methods affect the dimensional stability of removable acrylic resin orthoses. This analysis will facilitate the laboratory selection of a fabrication technique displaying minimal distortion and clinical use of an orthosis having a precise and accurate fit.

II. LITERATURE REVIEW

A. Terminology

The therapeutic use of interocclusal stabilization appliances, or intraoral orthoses, by clinicians has contributed significantly to the rehabilitation of dental patients suffering from disorders such as bruxism (53,66,114,137), acute or chronic temporomandibular joint pain (21,23,40,48,51,57,113,118,150,157), posterior condylar displacement (35,45,146), myofascial pain dysfunction (2,14,26,29,55,56,81,90,99,125), overclosed vertical dimension (30,52,97,98,149), and malocclusions (75,82,93,145).

In similar fashion, researchers have successfully utilized removable acrylic resin orthoses in their studies of the electromyographic activity of jaw muscles (25,36,72,77,91,133), the reproducibility of pantographic recordings (11,33,120), the duration of silent periods (13,15,96), and the relation of mandibular position to muscle strength (54,67,108,122,151,155).

Numerous articles (1,3,8-10,12,16-18,27,31,34,37,38,42-46, 59-62,64-68,71,75,80,83-89,95,102,103,109,117,123,124,126-129,134 136,139,142,144,147,156) and chapters (7,76,93,105,116,145) have been written describing various construction techniques for these interocclusal appliances. Widely varying terminology has been linked with specific appliance designs, fabrication techniques, and therapeutic uses, including many appliances bearing the author's own name. The common thread that connects all of the different oral orthoses, regardless of their names, is the idea

of keeping the teeth apart. How this goal is accomplished, and what purpose it is to serve, are the major sources of differences in the design and use of these appliances.

In Encyclopedia and Dictionary of Medicine and Nursing, orthosis is defined as a brace or other orthopedic device that is applied to an existing segment of the body for the purpose of protecting the segment or assisting in restoration or improvement of its function (94). In "A technique for construction of a temporomandibular occlusal stabilization splint - an orthotic appliance," Gjerde, Clark, and Solberg defined orthosis as an orthopedic appliance used to support, align, prevent or correct deformities or to improve the function of movable parts of the body (46).

Many of the concepts and terms used throughout this thesis, although commonly undefined, have been used descriptively by various investigators and authors in different ways. In Current Clinical Dental Terminology, Carl O. Boucher defined the following terms: bite guard, bite plane, bite plate, night guard, and occlusal splint (19). Some questions remain regarding the vagueness of these terms, as well as their utility and usefulness in prosthodontics.

In the Glossary of Occlusal Terms, the use of the term "oral orthosis" is recommended to help eliminate the confusion facing teachers and writers of scientific information by providing terminology that would make communication consistent and uniform (47).

B. Design and Fabrication Techniques

Although the terms "bite plane" and "bite plate" have been used interchangeably over the years, these devices were actually designed for different purposes. The bite plane was introduced into orthodontic use by Kingsley in 1872 (74). A vulcanite appliance, which covered the palate, sloped into a steep inclined plane anteriorly for guiding the mandible into a more forward position. It was hoped that eventually a retrognathic mandible would permanently retain this forward position. Kingsley was the first to perform this operation known as "jumping the bite."

In 1900, Ottolengui expressed the opinion that if an inclined plane on mandibular anterior teeth could retrude the psuedognathic jaw, the reverse could occur by placing an inclined plane on the maxillary anterior teeth (107). Ottolengui's bite plate was made of iridio-platinum fitted with clasps about the molars and a wire which came around the front of the arch. The plate was fitted with an inclined plane which was intended to jump the bite.

Karolyi, in 1906, recognized additional etiologic factors for "pyorrhea alveolaris", a condition he described and treated in 1901 with bite-raising gold crowns (69). He recommended treatment with a removable vulcanite splint to separate jaws, thus preventing trauma from worn and sharp migrated teeth that also wounded soft tissue (70).

In 1907, Angle used the inclined plane developed by Ottolengui as an active as well as a retaining device (40).

However, he noted that "jumping the bite" into an anterior position was ineffectual. This course eventually led him to introduce the use of intermaxillary elastics.

Hawley, in 1919, introduced a bite plane with a steeply inclined anterior plane (62). The principal use of Hawley's device was as a retainer rather than as a jaw positioner. The removable bite plane consisted of a rubber palatal plate fitting against the lingual surfaces of the teeth. From the plate, back to the cuspids, passed a 19-gauge gold wire which was formed into loops, and between them, passed over the labial surfaces of the incisors, was a flat wire. Attached to and extending backward from the 19-gauge wire was a bicuspid clasp. A flat ledge was built on the upper plate and extended in a bite plane to assist in correcting or holding *mesio*-distal relation where it was needed.

In 1933, Goodfriend incorporated vulcanite pyramids and smooth bite planes into a patient's maxillary and mandibular dentures (49). The patient had a history of dysarthosis of the mandible. On the lower denture on each side he constructed a pyramid. On the upper denture on each side he constructed a depression to exactly accomodate the lower pyramids. Smooth vulcanite planes were substituted for denture teeth in order to rest the mandibular articulation and to prevent occlusal trauma.

Sved, in 1944, analyzed the Hawley retainer and bite plate, and proposed that the original appliance must be modified in two important details in order to further improve its usefulness: 1)

the bite plate must be made tooth bearing instead of tissue bearing, and 2) the retention of rotated teeth must be more efficient (139). The Sved appliance consisted of a palatal or lingual base for the upper or lower teeth with an extension which covered the lingual surfaces of the six anterior teeth, then passed over the incisal edges and covered the incisal quarter of the labial surfaces.

In 1945, Sorrin presented a method for construction of a removable acrylic splint utilizing 21-gauge stainless steel wire for reinforcement and stabilization of periodontally involved teeth (134). Clear, heat-curing acrylic resin was used for processing the Sorrin splint.

Block, in 1947, fabricated temporary, trial appliances to establish and verify centric relation, balanced occlusion, and vertical dimension for treatment of disturbances of the temporomandibular joint (16). He preferred the use of cemented silver splints or a combination of partial dentures and splints, although he noted a persistent problem with depression of posterior teeth.

In 1952, Ingersoll and Kerens constructed vinyl resin splints to overcome occlusal trauma related to bruxism (66). The splint was designed for mandibular arch coverage to take advantage of gravity, flanges were extended buccally to the mucobuccal fold and lingually to correspond to the outline of a lower complete denture. The splint area covering the lingual and

buccal gingiva was thought to be tissue-stimulating because of the massaging action of the splint under stress.

In 1956, Stahl presented a simplified procedure for fabricating a temporary removable acrylic bite plate (136). The initial fabrication utilized a sheet of thick thermoplastic material heat-adapted to either the upper or lower cast. A roll of autopolymerizing acrylic resin was placed on the occlusal surface of the bite plate. The patient's centric relation position was then recorded in the self-curing resin.

Sears, also in 1956, used occlusal pivots to prevent or alleviate denture problems (126). The prime function of the pivot teeth was to permit the condyles to descend toward their unstrained normal positions. Elevations (pivots) were built on the molar teeth with autopolymerizing plastic material to hold opposing bicuspids and anterior teeth apart. Usually the first molar was the farthest posterior position for the pivot.

In 1957, Campbell applied a traction principle found in orthopedics to the temporomandibular joint and devised a resilient type of intraoral orthopedic appliance to gently open the joint space (21). His technique involved fabricating two splints - one with a flat occluding surface worn separately in the first stages of traction, and both splints (on opposing arches) worn when the muscles had relaxed somewhat.

Perlow, in 1958, described an acrylic attachment which was built onto the labial wire section of a removable acrylic bruxism appliance (109) or bite plate. He felt that an acrylic

attachment on the labial of a bruxism appliance was an innovative way to aid in resistance to forces generated by the noxious oral habit.

In 1959, Grupe and Gromek described the fabrication of a bruxism splint which was completely toothborne using "quick-cure acrylic materials that offer the possibility of an absolutely accurate fitting of such an appliance" (59). They felt that many bruxism splints, up to that time, had proven to be orthodontic appliances.

In 1960, Lackie adopted the use of a nightguard for treating the symptoms of bruxism (79). He advocated an occlusal equilibration be performed before fabricating the nightguard to correct occlusal disharmony. Lackie recommended construction of both an maxillary and mandibular splint when the patient presents with a gross occlusal discrepancy.

Odenheimer, in 1962, developed the "myotatic splint" to disrupt harmful jaw muscle action (103). The "myotatic splint" resembled other occlusal splints, except its greatest difference was its extent of occlusal correction. In fact, it strived for over correction. The splint raised the occlusal plane to such an extent that the patient could barely swallow. As soon as Odenheimer ascertained that the patient "had developed a new freeway space" while wearing his splint, a weaning off of the appliance was begun.

In 1963, Gecker and Weil described their fabrication of three bruxism appliances which tested the frequency, duration,

and severity of the bruxist oral habit (43). Indentations were fashioned intraorally by the patient into the occlusal surfaces of these night splints and were used to prevent the jaws from sliding or grinding against each other.

Courant, in 1967, recommended the use of removable acrylic resin splints in general dental practice to treat disturbing nonfunctional forces, bruxism, and tooth mobility (31). For Courant, poly(methylmethacrylate) afforded minimum porosity and ease of cleaning in construction of clear heat-processed acrylic resin splints.

Allen, the same year, described a technique for the fabrication of a retentive occlusal bite guard without the use of undercuts (3). All undercuts were surveyed on the stone casts and waxed out. The waxed bite guard was invested and processed with clear heat-curing acrylic resin. According to Allen, if properly fabricated, no adjustment should be needed to insert the appliance in the mouth.

Also in 1967, Shore recommended that biteplanes and Hawley biteplates should not be used in the treatment of TMJ dysfunction. Instead, he advocated his mandibular auto-repositioning appliance (128) to allow the patient alone to determine the physiologic placement of the mandible in centric relation. He attached a roll of autopolymerizing acrylic resin to the acrylic palate over the occlusal surfaces of the maxillary teeth. The patient's centric relation was then recorded and the acrylic was allowed to harden in the patient's mouth. Shore

eventually established freedom of movement of the mandibular teeth against the acrylic resin in all functional ranges of articulation.

Askinas, in 1972, proposed that a proper occlusal splint should be made of highly polished hard acrylic resin (8). He felt that clasp retention may not be necessary in a fully dentate arch, as the splint will probably derive enough stability and retention from its coverage of all the occlusal and incisal surfaces. Askinas used soft or medium baseplate wax to form the splint. He invested and processed the splint using clear, heat-curing acrylic resin. The splint was meticulously fitted in the mouth using soft disclosing wax. The accurate and complete seating of the splint on the teeth was of paramount importance to Askinas.

Also in 1972, Farrar presented a technique for construction of a specially modified maxillary bite plane to simplify treatment for temporomandibular joint dysfunction (38). The author designed mesial inclines for this appliance to occlude against the distal inclines of the mandibular teeth for diagnosis and treatment of anterior dislocation of the articular disc.

Shulman, in 1973, described a technique to circumvent time-consuming construction and adjustment procedures for fabricating a bite plane (129). He adapted two thicknesses of base plate wax to a maxillary cast, made centric registrations in the patient's mouth, and followed usual lab procedures to duplicate the wax bite plane in clear heat-cured acrylic resin. Shulman noted that

there may be problems in seating the completed bite plane in the mouth due to processing changes or undercuts. He acknowledged that if retention is a problem, clasps can be added at the time of the wax-up.

Horn, the same year, recommended the economical construction of bite planes utilizing a vacuum-adapted miniplast splint (65). She applied autopolymerizing acrylic resin in a tooth shade to the occlusal surfaces of the splint base while it was in the patient's mouth. Repeated closing movements were accomplished to ensure the positioning of the mandible in centric relation. The splint was allowed to complete polymerization in the mouth. Horn preferred to position the bite plane in the mandibular arch because it was least disturbing to the patient.

Also in 1973, Dyer presented a method of determining the stability of the TMJ through the use of a maxillary orthopedic appliance (37). The author noted that should the appliance disclose an instability of the TMJ, the same may be used in an attempt to achieve stability. Dyer outlined 17 steps for the construction of a maxillary orthopedic appliance. Of special interest was his use of a refractory duplicate of the maxillary cast to construct cast gold clasps to aid in retention of the appliance in the mouth.

Becker, Kaiser, and Lemm, in 1974, described a simplified technique for fabricating night guards using the Omnivac vacuum adaptation unit and clear autopolymerizing acrylic resin (12). Jet repair acrylic resin was mixed into a dough and manually

placed over the occlusal portion of a clear Omnivac resin sheet. The cast and affixed appliance were placed in a pressure pot at 100 degrees F for 15-20 minutes at 20 p.s.i. pressure. The fit of internal surfaces of the night guard were tested using disclosing wax. Becker recommended two methods for "solving retention problems": 1) reline the internal surface of the night guard with autopolymerizing resin intraorally, or 2) add ball clasps interproximally.

Becker pointed out that most previously reported techniques for construction of night guards had involved forming the appliance in wax. He noted how the investing and processing techniques were similar to those used for complete dentures. These procedures, he felt, were not only time consuming and expensive, but there was also "a certain amount of inevitable distortion in the night guards due to processing" (12).

Also in 1974, Kornfeld described a technique for fabrication of an acrylic resin bite guard or night guard utilizing a baseplate wax form molded over the occlusal surfaces of teeth on articulated casts (76). The casts were mounted in centric relation and cuspal interferences were removed by moving the articulator protrusively and through right and left lateral excursions. After processing in clear acrylic resin, the cured bite guard was seated on the casts and adjusted, again checking all excursive movements.

Lerman, the same year, presented a new type of fluid-bearing interocclusal appliance, the hydrostatic appliance (83). The

active element of the hydrostatic appliance was a thin, flexible-walled, H-shaped, fluid-bearing cell held between the posterior teeth by attachment to a plastic plate. Lerman proposed that the use of the appliance permitted maxillo-mandibular relationships to be self-established automatically by the patient's muscles. Unfortunately, the hydrostatic cells had to be replaced as leakage occurred when cuspal contacts penetrated the fluid-bearing cell (84).

In 1975, Langer introduced a palatal plate which could be constructed by the dentist for immediate use (88). Auto-polymerizing acrylic resin was used intraorally in a doughlike mass to construct a flat occlusal surface just lingual to the anterior teeth. Langer found the immediate palatal plate to be therapeutically beneficial for relief of TMJ pain, for reduction of occlusal trauma, and for orthodontic tooth movement.

Block, in 1976, presented a direct functional chew-in technique for construction of bite guards that can be accomplished in three short office visits (17). He utilized a functional bite tray plus hard baseplate wax on occlusal surface of the tray to record direct functional chew-in for bite registration. The waxed appliance was then processed in clear, heat-curing acrylic resin. Block acknowledged that the technique of making records of the dynamic relationships of the jaws (direct functional chew-in) was developed by Meyer in 1934.

In 1977, Timm and Ash recommended the full-coverage occlusal bite plane splint as an adjunct to orthodontic treatment (142).

The construction technique recommended by the authors was that of a clear, heat-cured acrylic splint obtained by waxing the splint on a maxillary cast mounted in an articulator. Desired cuspid guidance in lateral and protrusive excursions and small centric stops were obtained in the wax pattern. Processing of the splint followed conventional complete denture technique. The authors emphasized that occlusal bite plane splints should not be considered a permanent form of treatment, although they may be used for extended periods of time, as with bruxism.

Kass and Tregaskes, in 1978, felt that occlusal splints should be fabricated using orthodontic acrylic resin with a one-stage sprinkle-on technique (71). They postulated that the splint is usually constructed for the maxillary arch because it is possible to gain better retention and it is better tolerated. They employed the sprinkle-on technique to the vertical portion of the palate, as well as the buccal and occlusal surfaces of the teeth, to add stability, retention, and strength to the splint. The authors cautioned that premature removal from the cast would result in warpage of the acrylic resin frame. The bite registration surface of the frame was fabricated using manual dough application. The entire appliance was allowed to complete polymerization under air pressure.

In 1979, von Krammer presented a technique for construction of occlusal splints with the use of a surveyor to block out all undesirable undercuts (144). The appliance was waxed onto a

maxillary cast and processed according to complete denture flasking and processing techniques.

Adams, also in 1979, described a technique that "had as one of its advantages the accuracy and predictability of construction and fit" (1). He vacuum-adapted a clear resin splint over the maxillary cast, forming a template. Different waxes were added to the template to provide for a centric relation record and for adequate bulk for finishing the acrylic resin. Adams fitted the entire waxed splint and a stone index into a reline jig. He used autopolymerizing acrylic resin and processed the splint in 100 degrees F water and air pressure. Before he fitted the splint to the maxillary cast, he covered the cast with die relief agent or mercurochrome and applied a thin layer of cyanoacrylate adhesive. He then adjusted those areas that burnished and abraded the disclosed cast.

Adams concluded that the most important aspect of splint fabrication was obtaining a precise centric relation record at a fixed vertical dimension of occlusion. He felt that the advantages of using a vacuum-adapted template as the foundation for the splint were dimensional stability and smoothness. Adams further concluded that processing acrylic resin in water under compressed air produced splints which were dimensionally more accurate than heat or air cured acylic resin (1).

Lundeen, also in 1979, described the fabrication of an occlusal splint by vacuum mixing acrylic resin into a dough and adapting it over the maxillary teeth and to the edges of the

blockout wax on a maxillary cast mounted on an articulator (88). the author reasoned that vacuum evacuation of air from the mix before it reaches the dough stage resulted in a cooler, slower-setting, and denser acrylic resin. Lundeen conluded that with this construction technique the splint should fit accurately without rocking.

In 1979, Gelb reported the use of the mandibular orthopedic repositioning appliance (MORA) to treat craniomandibular syndrome (44). The Gelb appliance was constructed to cover the lower posterior teeth only. The author used a Galetti articulator for mounting the opposing casts and preferred to cure the the fast-setting acrylic appliance in a pressure cooker at 120 degrees F for 15 minutes.

Gjerde, in 1981, presented a technique for a maxillary occlusal stabilization splint that she said "provided for less dimensional change than previous heat-cured methods" (46). A baseplate wax pattern was flasked and processed using cold cure acrylic and the flasks were placed under 3500 lbs of pressure for only ten minutes. Utilizing this method, the authors concluded that the occlusal stabilization splint should routinely fit onto the maxillary teeth without difficulty.

Also in 1981, Rehany and Noah described a modified Hawley occlusal splint as it is used for oral rehabilitation (117). They constructed a flat, horizontal splint palatal to the maxillary anterior teeth, having a labial bow, and three-quarter clasps on the most posterior molars.

Okeson, in 1982, described the bite guard as a removable acrylic resin appliance that covers occlusal and incisal surfaces of the teeth on one arch and extends to the maxillary prominence of the facial and lingual surfaces of the teeth (105). He felt that the bite guard was a useful tool in the diagnosis and treatment of occlusion-related disease. Okeson's fabrication technique involved the use of a thick plastic resin sheet vacuum-adapted over the maxillary cast. The author used autopolymerizing acrylic resin to establish anterior centric contacts and eccentric guidance.

Also in 1982, Bates and Atkinson presented a method of fabrication of anteriorly-repositioned occlusal splints to treat anterior disc displacement (9). The principal concern of the authors with this type of treatment was the accuracy and repeatability of mandibular placement on the splint. They described construction of a splint that offered a reproducible position and could be used to reduce the chair time required for splint fabrication, delivery, and adjustment.

Hartman and Swepston, the same year, described a three-stage, sprinkle-on technique utilizing autopolymerizing orthodontic acrylic resin to fabricate a "mandibular stabilization prosthesis" (61). Their technique was based on the addition of separate sections of acrylic resin to the cast. Each section was allowed to complete polymerization before the next section was applied. The authors felt that this step-by-step technique "minimized warpage and ensured a more accurate fit of

the prosthesis" (61). The completed prosthesis was precisely fitted to the patient's maxillary teeth. Hartman and Swepston emphasized that all subsequent adjustments depended on this step. They concluded that their technique must be followed meticulously to achieve the desired results.

In 1983, Klineberg presented a critical assessment of the use of full-coverage occlusal appliances in prosthodontics (75). To be effective, he emphasized that such appliances must be designed correctly and regularly adjusted following fitting to maintain stability and provide balanced jaw support during excursive movements. The design of the splint, according to Klineberg, should ensure coverage of the lingual and occlusal surfaces and 2-3 mm of the labial and buccal surfaces of the teeth. The splint should be processed in clear heat-cured acrylic resin and have sufficient bulk to permit adjustment on it occlusal aspect.

Bates et al, in 1984, presented a method for the single appointment fabrication of a maxillary occlusal splint (10). A splint base was made of clear splint material vacuum-formed over the patient's cast. Cold-curing resin was applied in a doughy stage to the occlusal surface of the splint base to custom fit the occlusion intraorally. The procedure described required approximately 90 minutes of patient time, of which 30 minutes was actual chair time. The authors cautioned that this splint would not last as long a heat-processed acrylic splint, but usually

lasted several months, often long enough to relieve acute TMJ dysfunction symptoms.

Most recently, in 1987, Haddix reported a simplified technique for rapidly producing a mandibular occlusal splint using a visible light-curing denture base system (60). The author claimed that the occlusal splint appears clinically to be more durable than those made of the traditional orthodontic autopolymerizing acrylic resin. Also, he mentioned that the visible light-curing acrylic resin offers the working time necessary to mold the splint to the exact form desired.

In retrospect, the common thread that connects interocclusal stabilization appliances, regardless of their origin, is the idea of keeping the teeth apart. How this goal is accomplished, and what purpose it is to serve, are the major sources of differences in the design, fabrication, and use of orthoses.

Numerous design features and construction techniques have been proposed and developed to cope with the inherent problems of distortion of removable acrylic resin orthoses. The ideal acrylic resin applicance should be dimensionally stable, well-retained, and easily fabricated in the dental office or laboratory (75). Although many of these design features can be incorporated into orthoses constructed of hard acrylic resin there continue to be functional characteristics that may result in adverse oral symptoms.

Clinicians and researchers have pointed out that tooth movement (63), periodontal ligament changes (119), temporo-

mandibular joint pain (23,101,148), and a variety of other problems (20) may be experienced by dental patients. While these clinical problems are significant, they represent symptomatic problems that may be related to the forces produced by distortion inherent in acrylic resin orthoses.

Brayer and Erlich reported on the uses and dangers of occlusal night guards (20). They studied night guards made from wax models processed in acrylic resin according to the technique of complete dentures. The authors noted: 1) intrusion of posterior teeth due to wearing a night guard without interruption, 2) tooth migration, 3) occlusal trauma, 4) increased caries, and 5) increased gingival inflammation.

Weinberg emphasized that acrylic resin treatment protheses should be supervised constantly (147). He remarked that severe occlusal mutilation can result if a patient wears an acrylic resin treatment prosthesis for extended periods of time.

In contrast, though, Ramfjord and Ash have stated, "by far the best appliance for patients with dysfunctional symptoms is the occlusal splint, which covers all of the teeth either in the maxilla or mandible. If the splint is made from casts mounted on an articulator and the acrylic is heat-cured, it is fairly easy to fit the splint in the mouth. The complete coverage splint can be used for any length of time since it does not allow the teeth to move" (115).

Removable acrylic resin orthoses of various designs have been used extensively for research (11,13,15,22,25,33,36,51,54,

91,96,108,110,120,122,133,155), prosthetic rehabilitation (75,82, 93,98,121,145,146,148-150,152), and intraoral protection (34,64, 73,89,102,138,156). These appliances are widely recommended in dentistry and medicine even though they are empirical in design and fabrication method. Still, no definitive study has been made to evaluate the dimensional stability provided by different fabrication techniques and storage methods.

C. Dimensional Stability Research

The analysis of the dimensional stability of acrylic resins has been well documented in the literature. Since the introduction of acrylic resin denture base material in 1937, investigators have used a variety of methods to determine the dimensional change during processing and storage, and the subsequent fit of dentures.

In 1939, Sweeney studied the effect of change in environment on warpage of a denture made from acrylic resin (140). He fabricated dentures and replaced them on stone models after fifteen days storage at 37° C. The amount of space between the denture and the stone model indicated the fit. Sweeney also devised a stainless steel alloy shrinkage test block and a pyrex glass plate with etched lines to determine percent shrinkage of denture base materials during curing.

Sweeney, Paffenberger, and Beall reported in 1942 on the physical, chemical, and mechanical properties of thirty acrylic resins (141). In order to study the dimensional change that took

place during alternate wetting and drying, they placed gauge marks on each processed denture just posterior to the last teeth. The distance between the gauge marks was measured with a micrometer microscope after each denture was placed on a gypsum model and repeatedly wetted and dried. In general, the dentures increased in dimension on immersion and decreased in dimension on drying.

Sweeney et al also utilized stainless steel dies to determine linear shrinkage during curing[141]. Acrylic resin forms were molded on the stainless steel die, which at certain points had fine cross-line reference marks. These marks were transferred to the resin forms during molding. The difference in distance between the reference marks on the die and resin forms represented the shrinkage of the acrylic resin during processing.

In 1943, Skinner and Cooper processed acrylic resins directly against special brass models in order to eliminate any variables contingent upon the stability of a stone cast (130). The metal models represented diagrammatically the posterior section of an upper edentulous mouth. They observed at least two dimensional changes which are unavoidably active in every acrylic resin denture; namely, shrinkage, which occurs during processing, and, subsequently, expansion, which occurs upon immersion in water.

Caul and Schoonover described in 1949 a chemical method for determining the degree or completeness of polymerization of acrylic resins used for dentures (24). They applied their method

to the investigation of irregularly shaped objects which they felt cannot be tested by conventional methods. The authors concluded that lower transverse strength of thin sections of dentures, as compared to thick sections, was the result of less complete polymerization in the thin sections.

One of the advantages of the self-curing resins for the construction of denture bases was assumed to be accuracy of fit. All observations on this subject appeared to be somewhat qualitative and subjective with the exception of those made in 1952 by McCracken (92). He found by measurement that the linear curing shrinkage of the self-curing acrylic resins was less than that for the heat-curing resins, and that the shrinkage was compensated for after a five-day immersion in water.

Also in 1952, Grunewald, Paffenberger, and Dickson utilized a stainless steel die to stimulate the shape of the denture bearing surface of an edentulous jaw to study the effect of molding processes on denture resin (58). Reference marks (A,B,C,D,E,F) were ruled at varying points along the posterior section of the die. These marks were transferred from the die to the acrylic resin form during curing. The difference between the two most lateral marks (A,F) on the die and on the denture form was used as a measure of the linear shrinkage which occurred during processing. The greatest change in dimension occurred on removal of the denture from the model.

With McCracken's previous observations in mind, Skinner and Jones investigated in 1955 the dimensional stability of

self-curing denture base acrylic resins (131). The master model used throughout this study was an edentulous maxillary reproduction, cast in aluminum with no undercuts. Gauge marks were cut on the casts in the posterior ridge area. The distances between the gauge marks were measured, and compared with the distances between their impressions in the denture bases and dentures constructed. The percentage of difference between the gauge marks on the casts and those in the resin was assumed to be a measure of the accuracy of fit in these regions.

Skinner and Jones concluded that the curing shrinkage of the denture bases made with self-curing acrylic resin was definitely less than that of bases constructed with the heat-curing resin (131). They also noted that when the self-cured denture base was allowed to remain in air, a further shrinkage occurred, presumably the result of a further polymerization of the resin. Immersion of the denture bases in water at 37° C resulted in a gradual increase in size in all instances. After an immersion of six weeks, the self-cured denture bases were approximately as much oversize as the heat-cured bases were undersize.

In 1958, Mowery et al reported on the dimensional stability of denture base resins (100). Measurements of the dimensional changes during processing and during a period of two years of clinical service were made on a series of dentures. To provide reference points for determination of dimensional changes, stainless steel pins, polished on one end and ruled with fine cross marks, were cemented in the central fossa of the last

molars (A,B) and in the distobuccal peripheral flanges (C,D) of the self-cured and heat-cured acrylic resin dentures. All measurements were made at 70° F on a toolmaker's microscope and recorded to the nearest 0.0001 inch. The researchers computed and graphed the percentage change in dimension between the reference points. Readings were made on the waxed-up model prior to processing; after removal from the cast on the denture just prior to insertion; at 30-day intervals for six months after delivery to the patient; and then at six-month intervals.

Anthony and Peyton, in 1959, evaluated the dimensional accuracy of denture bases with a modified comparator (5). For this study, a method was developed using a modified comparator for reproducing denture contours in their relation to a master model in such a manner that the discrepancies at any point may be measured as the shortest distance between the contour lines. The comparator is essentially a pantograph which measure the vertical distance between corresponding points on the surfaces of two similar objects.

The dimensional changes occurring in dentures during processing were investigated in 1960 by Woelfel, Paffenberger, and Sweeney (153). They measured vertical discrepancies in occlusal relations of dentures processed with different acrylic resin denture materials. They also made linear measurements on each denture (molar-to-molar) at various times at 72° F. The reference marks were fine cross lines ruled on polished stainless steel pins cemented in the second molars and in buccal flange

borders of mandibular dentures. The relative deformation (distortion) of the posterior section of the dentures was judged by the molar to molar and flange to flange shrinkage.

Woelfel determined the relative accuracy of the fit of the dentures in this study (153) by: 1) comparing the position of the incisal guide pin before and after curing; 2) measuring molar to molar shrinkage from the wax model denture to the polished denture; 3) examining crossections of cured dentures surrounded by the flasking gypsum; 4) noting the fit of polished dentures on the casts on which they were cured; and 5) observing the relative fit of the dentures in the mouth.

The following year, the same investigators studied the changes in dentures during storage in water and in service (154). They developed a warpage index for this report and defined it as the difference in percentage change between the molar-to-molar and the flange-to-flange distances. For example, if a denture expanded or shrank proportionally over the molar-to-molar and the flange-to-flange distances, its warpage index would be zero. However, if it expanded molar to molar and shrank flange to flange, or if the shrinkage or expansion over the two distances was greatly out of proportion, the warpage index would be relatively high. In this study, the warpage index ranged from 0.00 to 0.61 percent. The researchers also compared the relation between the fit of the clinical dentures on the gypsum cast on which they were cured and the changes in molar-to-molar and flange-to-flange distances.

Anthony and Peyton, in 1962, evaluated the accuracy and fit of dentures made of various materials utilizing their modified comparator for measuring denture contours (6). They found the most accurately fitting dentures to be of the self-curing acrylic resin type. The authors attributed this to the fewer processing strains which result from low curing temperatures. Heat-cured dentures of different brands did not fit as well as self-cured ones, but, nonetheless, were considered good.

The following year, Peyton and Anthony evaluated dentures processed by different techniques (111). They determined by means of a modified comparator the exactness of the duplication of dentures from the final impression and the accuracy of fit of dentures made of various materials. The authors concluded that the most accurate dentures were invariably of the self-curing type. In general, it was determined that the self-curing method of processing offered the simplest method and involved the least amount of equipment. Self-curing materials should especially find application for repairs and relining, since the application of heat causes warpage of plastic dentures.

In 1967, Smith, Lord, and Bolender reported on complete denture relines processed with autopolymerizing acrylic resin in water under pressure (132). They evaluated the dimensional accuracy of this reline technique. A metal die shaped to simulate a maxillary arch was used as a standard. It was semicircular in shape with a diameter of 6.7 cm. The buccal and palatal tapers were equal. The investigators measured the space

in inches between the relined samples and the die. The results obtained showed a significant difference between the auto-polymerizing 100° F relines and the heat-cured relines. The authors concluded that processing in water under compressed air produced relines which were dimensionally more accurate than heat-cured relines.

In more recent times, Craig (32) has recommended that autopolymerizing acrylic resins should be processed in water under pressure. He also has suggested several curing methods to improve the "quality" of acrylic resin restorations and prostheses.

Stafford, Bates, and Huggett, in 1983, reported on the dimensional accuracy of orthodontic base polymers (135). Seven orthodontic base resins were examined and compared with a conventional heat-cured resin, a high-impact rubber-added resin, a dough-molded autopolymerizing resin, and a pour-type resin. The orthodontic resin specimens were produced using an "infiltration" technique, more commonly referred to as the sprinkle-on additive technique. The dimensional accuracy of the orthodontic resin materials was measured using the method of Goodkind and Shulte (50). A modified master metal die was made so as to approximate more closely the tooth-coverage limits of removable orthodontic appliances. The dimensional accuracy of the materials tested was reported to be good. The amount of "contraction" in all cases was less than 0.6 percent. After saturation in water for one month the expected expansion took

place, and this was very apparent at the posterior dimension. However, the orthodontic resin bases were in all cases within one percent of the original dimension of the stone cast.

In 1985, O'Toole, Furnish, and vonFraunhofer investigated the effect of five polymerizing methods on the dimensional stability of cold-curing acrylic resin (106). The authors evaluated the same curing methods as reported in their 1983 transverse strength study (41); namely, 1) bench polymerization, 2) curing under a coating of petroleum jelly, 3) curing in a monomer atmosphere, 4) polymerization under pressure in air, and 5) curing under air pressure in water. The linear distortions of acrylic resin block specimens formed by a one-stage sprinkle-on technique were measured and differences between means statistically evaluated.

The researchers in this study (106) concluded that there was a tendency for specimens cured under air and water pressure to exhibit greater linear dimensional change, i.e. greater distortion, than specimens cured on the bench, in a monomer atmosphere, or coated with petroleum jelly.

Fehling, Hesby, and Pelleu reported in 1986 on the dimensional stability of autopolymerizing acrylic resin impression trays (39). Two commonly used methyl methacrylate autopolymerizing tray resins were evaluated. All trays were made on a custom ground aluminum tray former. Linear dimensional changes were recorded periodically between five reference pins that were transferred from the master die to the trays.

Reference pins (A,B,C,D,D') were located on the borders of five flange sites.

In this study (39), significant linear dimensional changes were observed for only 40 minutes from the initiation of tray fabrication. The authors concluded that while an aged tray (more than 24 hours) may be preferred, it is acceptable to make an impression in an autopolymerizing resin custom impression tray after 40 minutes.

Most recently in 1986, Ogle, Sorensen, and Lewis evaluated Triad Visible Light Curing (VLC) resin as a denture base reline material in comparison to heat-cured (HC) and autopolymerizing (AP) acrylic resin denture base reline materials (104). They used an edentulous maxillary dental stone cast with metal markers at five posterior palatal locations to measure dimensional stability. Each stainless steel pin was imprinted with a Rockwell Brale Diamond Penetrator and cemented in a prepared channel with epoxy cement.

Dimensional changes of the denture bases were evaluated by fabricating VLC, HC, and AP bases on identical casts. Horizontal measurements between pins, and vertical measurements (palatal lift), were recorded under dry conditions and after the bases had been soaked in water for 10 days. After 10 days in water, the AP acrylic resin showed a +0.05% expansion from ridge crest to ridge crest, VLC showed a -0.14% contraction and HC acrylic resin showed a -0.40% contraction. The authors concluded that visibile light-cured acrylic resin is "generally superior in fit compared

to heat-cured and autopolymerizing acrylic resin denture base reline materials" (104).

In retrospect, the basis for this research project is the fact that since the introduction of acrylic resin denture base material in 1937, there have been many suggested variations in fabrication techniques and storage methods for these materials. Often these variations have been introduced with a claim of superior properties, improved accuracy of fit, and greater dimensional stability in service. The full significance of these empirical claims on the function and performance of an orthosis in service has not always been clear.

Because of the advantages claimed for the various acrylic resin materials and the modified fabrication techniques that have been introduced in the literature over the years, an evaluation of their effect on dimensional stability should be considered desirable at this time.

III. RESEARCH OBJECTIVES

Removable acrylic resin orthoses have been used extensively by dental practitioners in the diagnosis and treatment of dentofacial disorders. These appliances allow for a decrease in muscle fatigue, spasm, tenderness, joint edema, inflammation, tooth mobility, sensitivity, and a tendency to diminish or eliminate bruxism (143). However, the effects of orthoses on dental structures have not been completely understood, and the treatment has often led to failure (20,147). For this reason, widely varying opinions exist among clinicians and researchers concerning the design and construction of interocclusal stabilization appliances.

The primary objective of this investigation is to construct removable acrylic resin specimens, utilizing various fabrication techniques for orthoses described in the literature, and to visualize and quantify their linear dimensional change, with a measuring microscope.

An original research model has been designed and will provide for analyzing the dimensional stability produced by five different fabrication techniques and two different storage methods. The validity of this type of investigation depends on the relationship between the model and the original structure it represents. Although the linear dimensional change to be observed should be predictable based on previous research, this study hopes to determine the effects of fabrication techniques

and storage methods on the dimensional stability of acrylic resin orthoses.

IV. METHODS AND MATERIALS

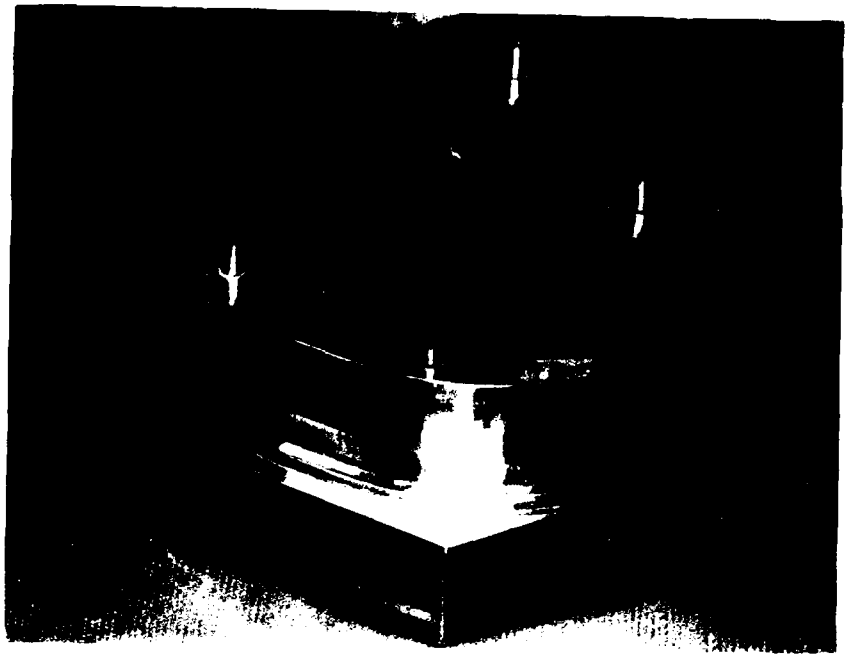
A. Design of Research Model

A computer designed and machined master aluminum die was fabricated to serve as an original research model for this investigation. The aluminum die was designed and constructed utilizing the average dimensions, reported in a study on athletic mouthguards (78), for a human dentate arch (see Plate 1).

An average arch length of 130 mm and an average arch height of 18 mm was proposed for the research model. An 11 mm arch width at the second molar, a 7.5 mm arch width at the canine, and a 3 mm arch width at the anterior midline were also incorporated into the design. In addition, a 5 degree buccal taper and a 7 degree lingual taper were selected for the research model. Finally, two millimeter diameter cylindrical depressions at the second molar and canine areas were placed to provide intra-arch distances between the depressions of approximately 35, 50, and 25 millimeters.

An engineering drawing containing the desired dimensions was completed by Dr. Kirk Satrom, Dental Investigative Service, Brooks AFB, Texas. Verbal discussions were held with Mr. McDougall, Supervisor, Materials Laboratory, Brooks AFB, Texas and Mr. Heinz Jaeger, Machinist, Materials Laboratory, Brooks AFB, Texas for the computer design and fabrication of the original research model. Mock-up models of wood and plastic were

Plate 1. Computer designed and machined aluminum research model with paralleled brass Pindex pins.



made by Heinz Jaeger prior to final fabrication of the aluminum research model.

The mock-up models were an invaluable aid as several changes to the original design were necessary. In particular, the lingual surface of the arch was given a 7 degree taper instead of 15 degree, and was shortened in height from 18 mm to 13 mm. Also, locations of the anterior cylindrical depressions were moved approximately 5 mm distally from their original locations.

Numerous photographs were made documenting the sequential sculpting of the research model from a block of aluminum by a computer programmed milling machine.

B. Fabrication of Research Casts

Following fabrication of the research model, a surveyor was utilized to parallel placement of Pindex brass pins (long) into the cylindrical depressions. Polyvinylsiloxane impression material was used to secure the pins in centered and paralleled positions. The long Pindex pins were replaced with short Pindex brass pins. The entire research model was placed in a duplicating flask and impressed with irreversible hydrocolloid (56 grams) mixed with 350 cc distilled water. The irreversible hydrocolloid was vacuum mixed with distilled water for 45 seconds t. produce a smooth, runny, bubble-free mixture for duplication. The impression material was allowed to set for five minutes.

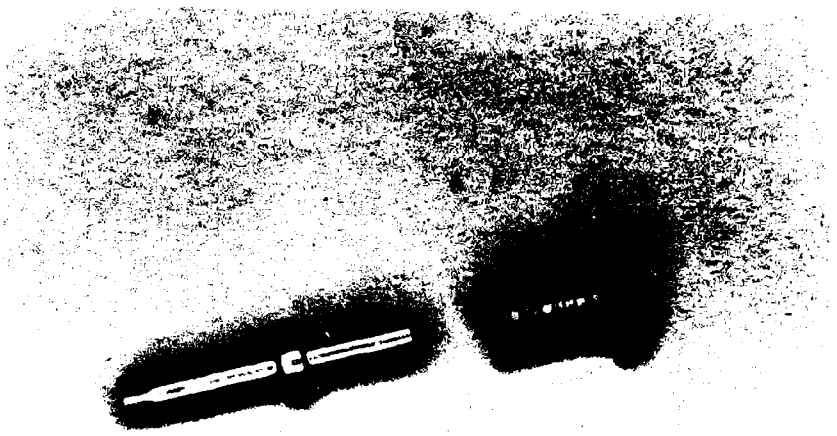
After removal of the aluminum research model from the irreversible hydrocolloid impression in the duplicating flask,

Pindex brass pins (short) and altered grey plastic sleeves were placed into the depressions in the impression. The grey plastic Pindex sleeves were altered by shortening their length to coincide with the longest end of the short Pindex brass pins. Each plastic sleeve was then removed and replaced on its accompanying brass pin in a reversed position (see Plate 2). This allowed for the grey plastic sleeve to be securely retained in the fabricated stone cast.

To complete the fabrication of each research cast, one hundred fifty grams of Die-Keen improved dental stone (Modern Materials, Columbus Dental) was combined with thirty-five cc of distilled water and vacuum-mixed at 1725 rpm for thirty seconds under 710 mm mercury vacuum using a Vac-U-Mix Combination Unit Vacuum Mixer (Whip-Mix Corporation, Louisville, Kentucky). Following placement of the four Pindex pins and attached grey plastic sleeves into the depressions in the impression in the duplicating flask, the Die-Keen improved dental stone mixture was vibrated into the impression with the use of a Toothmaster Investment Vibrator, Whaledent International. The dental stone was allowed to set for one hour at which time the completed research cast was withdrawn from the impression material.

After complete drying of the research casts, each embedded pindex pin was removed, cleaned, and inverted to provide a metal flange approximately 1.0-1.5 mm above the stone cast surface. The metal flange would serve as a retentive undercut-locking mechanism for each pindex pin during fabrication of the acrylic

Plate 2. Grey plastic sleeve modified for insertion onto brass Pindex pin. Plastic sleeve will be retained in die-stone research cast.



resin specimen. Prior to inverting each pindex pin, an abrasive disk was used to place vertical grooves in the metal flange to serve as anti-rotational locking mechanisms (see Plates 3 and 4).

Each cast was labeled with a capital letter, a number, and a lower case letter to respectively designate the design, specimen number, and method of storage. For example, the first five casts were labeled: A-1(w), A-2(d), A-3(w), A-4(d), and A-5(w).

C. Fabrication of Specimens

Five specific design and fabrication techniques, representative of those reported in the literature, were utilized to construct fifty removable acrylic resin orthotic specimens. Ten specimens were fabricated on individual die-stone casts for each of the *five fabrication techniques*. All acrylic resin specimens were produced in the same laboratory using standardized conditions and materials.

The outline, thickness, and overall dimensions of all specimens were made to approximate each other, not only within each design set, but also among all of the designs. The design of each specimen ensured coverage of the lingual and occlusal surfaces (2-3 mm thick) and 2-3 mm of the buccal surfaces of the research cast arch form.

The five fabrication techniques consisted of a one-stage sprinkle-on autopolymerizing acrylic resin application technique (Design A), a three-stage sprinkle-on autopolymerizing acrylic resin application technique (Design B), an autopolymerizing

Plate 3. Brass Pindex pin inverted in die-stone research cast. Vertical grooves and metal flange provide for anti-rotational and mechanical lock of pin to specimen.

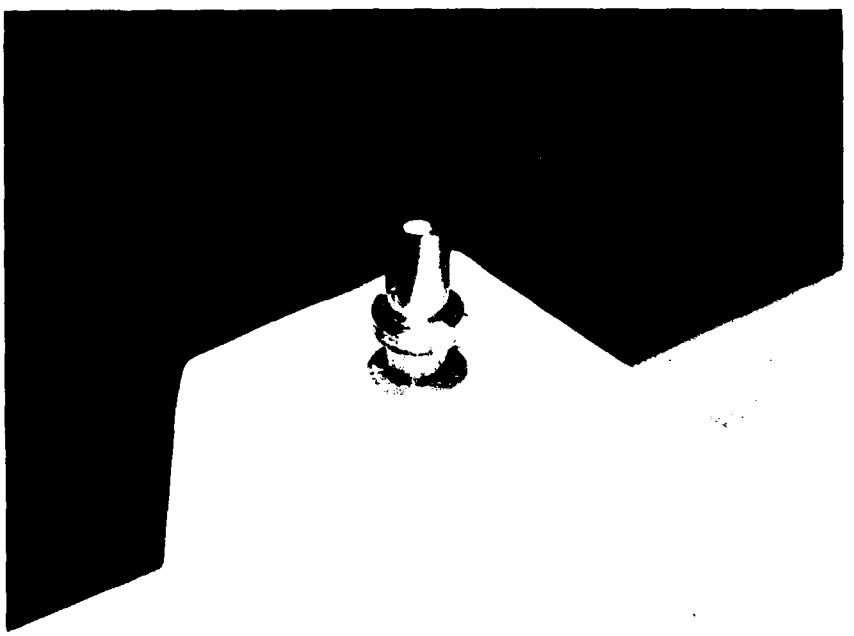
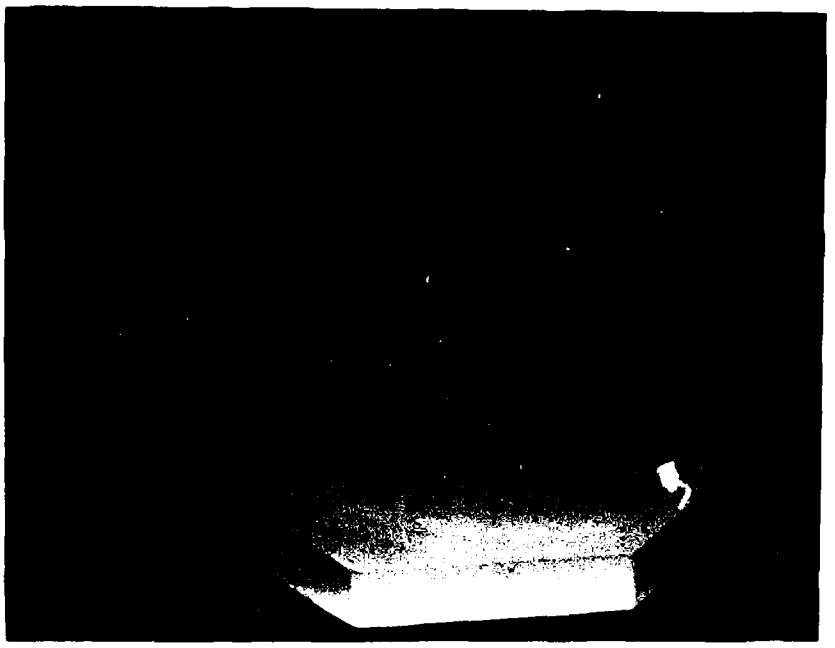


Plate 4. Die-stone research cast with designated pin locations A, B, C, and D. Outline form for specimen indicated by pencil line.



acrylic resin dough application technique (Design C), a vacuum-adapted resin sheet and autopolymerizing acrylic resin dough application technique (Design D), and a heat-cured acrylic resin denture processing technique (Design E).

Design A consisted of a one-stage sprinkle-on technique of autopolymerizing orthodontic acrylic resin (Caulk Orthodontic Autopolymerizing Clear Acrylic Resin). Wax-up of the border outline of each specimen was accomplished using pink baseplate wax (Hygienic Type II medium wax). Two layers of Al-Cote (tin foil substitute) separating medium were applied to the buccal, occlusal, and lingual surfaces of each die-stone research cast. Autopolymerizing orthodontic acrylic resin (monomer and polymer) was sprinkled on to the buccal, occlusal, and lingual surfaces of each cast, with a sprinkle-on additive technique, from second molar area circumferentially around the arch to the opposite second molar area. Each completed specimen of Design A was allowed to complete polymerization in air on a laboratory benchtop for a minimum of 60 minutes.

Design B consisted of a three-stage sprinkle-on technique of autopolymerizing orthodontic acrylic resin (Caulk Orthodontic Autopolymerizing Clear Acrylic Resin). Wax-up of the border outline of each specimen was accomplished using pink baseplate wax (Hygienic Type II medium wax). Two layers of Al-Cote (tin foil substitute) separating medium were applied to the buccal, occlusal, and lingual surfaces of each die-stone research cast. Autopolymerizing orthodontic clear acrylic resin (monomer and

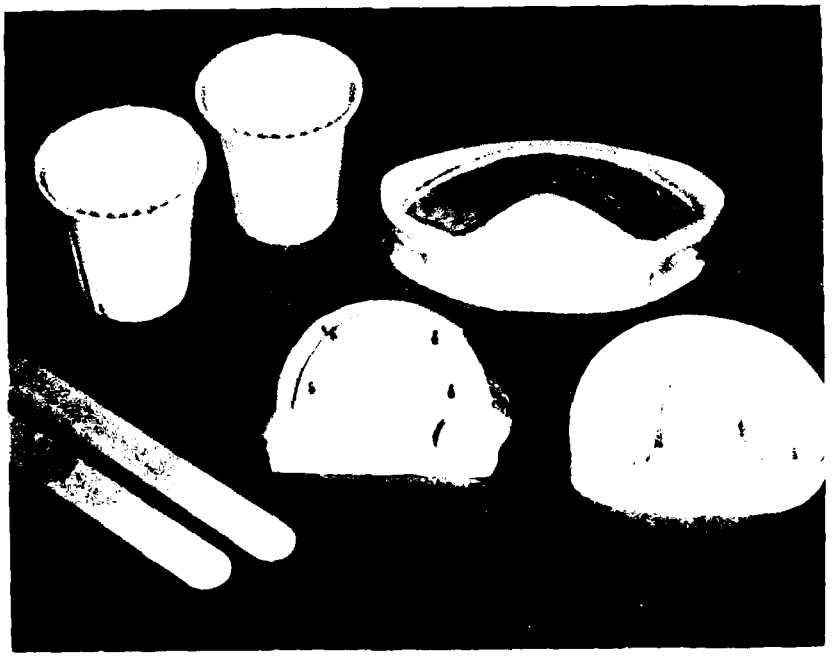
polymer) was sprinkled on to the buccal, occlusal, and lingual surfaces of each cast, with a salt-and-pepper additive technique, in three separate sections. Each section (two posterior and on anterior) was allowed to polymerize in air on a laboratory benchtop for twenty minutes before proceeding to the next section. The right posterior section was formed first (reference pin D included in this section), then the left posterior section (reference pins A and C included in this section), and finally, the two posterior sections were connected by forming the anterior section (reference pin B included in this section). Thus, each completed specimen of Design B was fabricated based on the addition of separate sections of acrylic resin to the research cast.

Design C consisted of autopolymerizing acrylic resin (Caulk Orthodontic Autopolymerizing Clear Acrylic Resin) mixed into a dough and manually adapted over the research stone cast. Two layers of Al-Cote (tin foil substitute) separating medium were applied to the buccal, occlusal, and lingual surfaces of each die-stone research cast. A powder to liquid ratio of 2:1 using 16 cc of polymer and 8 cc of monomer, measured in graduated cylinders, provided an adequate amount of acrylic resin dough for each specimen.

A Die-Keen stone mold was developed for shaping the acrylic resin dough prior to application of the dough to individual research casts (see Plate 5). The stone mold was approximately 3 mm in depth with four cylindrical elevations to aid in placement

Plate 5. Armamentarium developed for fabrication of Design C and Design D specimens.

1. Die-Keen stone mold to shape acrylic resin dough.
2. Polyvinylsiloxane mold on research cast.
3. Die-Keen stone cap to maintain appropriate outline form and thickness.



of the dough onto the casts so as not to disturb the pindex pins. In the non-tacky handling stage, the dough demonstrated a rubbery, springy consistency and a stone cap was used to shape the dough and maintain an appropriate outline form and thickness during fabrication of each specimen.

A small amount of autopolymerizing acrylic resin was mixed and placed in a "runny" consistency around the pindex pins of each research cast to enhance the mechanical lock of the fabricated specimen to the pins. This "runny" mixture was placed on the cast immediately prior to the application of the acrylic resin dough. Each completed specimen of Design C was allowed to bench cure under normal atmospheric conditions.

Design D consisted of a clear .060" Omnivac resin sheet (Buffalo Dental Co.) adapted over a research cast with autopolymerizing acrylic resin (Jet Clear Autopolymerizing Acrylic Resin, Lang Mfg.) mixed into a dough and manually placed over the Omnivac resin sheet. Two layers of Al-cote (tin foil substitute) separating medium were applied to the buccal, occlusal, and lingual surfaces of each die-stone research cast. A .060" clear resin sheet was vacuum-adapted over each cast. The resin sheet was trimmed with a straight acrylic bur to the appropriate outline and dimensions marked in blue pencil on each cast. A powder to liquid ratio of 2:1 using 12 cc of polymer and 6 cc of monomer, measured in graduated cylinders, provided an adequate amount of acrylic resin dough for each specimen.

A Die-Keen stone mold was developed for shaping the acrylic resin dough prior to application of the dough to the vacuum-adapted resin sheet on the individual research cast. The stone mold was approximately 3 mm in depth with four cylindrical elevations to aid in placement of the dough onto the resin sheet so as not to disturb the pindex pins. In the non-tacky handling stage, the dough demonstrated a rubbery, springy consistency and a stone cap was used to shape the dough and maintain an appropriate outline form and thickness during fabrication of each specimen.

A small amount of autopolymerizing acrylic resin was mixed and placed in a "runny" consistency around the pindex pins and on the buccal, occlusal, and lingual surfaces of the resin sheet. This application enhanced the mechanical lock of the specimen to the pins and the chemical retention of the resin sheet to the acrylic resin dough. The entire cast and affixed, fabricated specimen was placed in a pressure pot and allowed to cure at 100° F for 15 minutes at 20 p.s.i. pressure.

Design E consists of two thicknesses of baseplate wax (Hygienic Type II Hard Wax) adapted over a research cast and duplicated in clear heat-curing acrylic resin (Plastodent) following standard laboratory procedures for processing complete dentures. Each die-stone research cast was waxed to the appropriate outline and dimensions as marked in blue pencil on each cast. The completed wax-up and cast were invested using Type II yellow dental stone and flasked in a maxillary denture

flask in three stages (drag, cope, and cap). Prior to investing the cap portion of the flask, polyvinylsiloxane impression material (Reprosil Light Body) was placed over each of the four pindex pins protruding from the wax-up (see Plate 6). This elastomeric impression material allowed for separation of the flask during packing and divestment without dislodgement of the pindex pins.

Flasks containing the invested wax-ups for specimens were placed in a boil-out tank for seven minutes. The flasks were opened and wax residue removed by flushing with hot water. Wax solvent was placed on the casts and all invested stone parts were again flushed thoroughly with hot water. A diluted detergent and water solution was placed on the casts and thoroughly flushed with hot water. Each invested stone portion of the denture flask was allowed to bench cool and dry to room temperature, then painted with two layers of Al-Cote separating medium (tin foil substitute).

Heat-curing clear acrylic resin (Plastodent) was supplied in the form of a powder and a liquid. Twenty (20) grams of polymer was added to ten (10) milliliters of monomer in a porcelain jar and stirred for thirty (30) seconds. The jar was covered and allowed to stand until a soft putty-like consistency was obtained, in approximately 7-10 minutes, with no stickness evident. The temperature of the flask corresponded to that of room temperature (23^{o} C). A doughy roll of material was carefully placed into the cavity of the flask to avoid

Plate 6. Die-stone research cast waxed to appropriate outline and thickness for fabrication of Design E specimen. Elastomeric impression material protects pindex pins during flasking, packing, and divestment.

overpacking. The flask was closed and placed in a press. The press was closed very slowly, making half turns in the process, and taking approximately half a minute each turn. The complete procedure took 2-3 minutes. The flask was then allowed to stand for a few minutes as the material flowed into position. The flask was opened and it was ascertained if it had been packed sufficiently. Acrylic resin dough material was trimmed away at the edges of the specimen or added to deficient areas; the flask was then placed in the press and final closure was completed.

The packed flasks were allowed to bench set for 30 minutes and then placed in room temperature water in a Hanau curing unit. The flasks were heated for 90 minutes at 73° C followed by 30 minutes at 100° C. The flasks were removed from the curing unit after cooling of the water to room temperature. The flasks were divested and the acrylic resin specimens affixed to their casts were recovered intact (see Plate 7).

D. Storage of Specimens

After construction, initial measurement, and removal from their individual die-stone research cast, each specimen was stored in either a wet or dry environment for the duration of the study. Fifty percent (50%) of the available specimens from each design group were selected and stored in water at room temperature (wet storage condition). The remaining specimens were stored in air at room temperature (dry storage condition).

Plate 7. Design E specimen representative of the appropriate outline form and thickness obtained for all removable acrylic resin specimens.

To facilitate storage in water or air at room temperature, Zip-Lock storage bags were labeled with the design, specimen number, and method of storage (see Plate 8). For example, the first ten specimens were labeled: A-1(w), A-2(d), A-3(w), A-4(d), A-5(w), A-6(d), A-7(w), A-8(d), A-9(w), and A-10(d).

After initial measurement, each acrylic resin specimen was removed from its individual die-stone research cast and placed in its respective storage bag, designated either wet storage condition (w) or dry storage condition (d). A two-inch cotton roll was placed in a graduated cylinder containing 10 cc of distilled water. The moistened cotton roll and the remaining unabsorbed distilled water were placed into the wet storage bags to provide the wet storage condition. The dry storage bags contained only their acrylic resin specimens.

E. Measurement of Casts and Specimens

As a method to determine the dimensional stability of removable acrylic resin orthoses, the distances between the inside diameters of the four pindex pins were measured with a linear measuring microscope (Gaertner Scientific Corp., Chicago, Ill.). These distances were labeled A-B, C-D, A-C, and B-D and respectively designated anterior, posterior, left, and right reference lines (see Plate 4).

Baseline measurements were made of the distances between the edges of the pins at their nearest points to each other and recorded at the following time periods:

Plate 8. Zip-lock storage bags labeled with design, specimen number, and storage condition (wet or dry).

INITIAL MEASUREMENT, on die-stone research cast;

ON CAST, after fabrication of specimen;

0 HOURS, specimen off cast;

24 HOURS, specimen stored wet or dry;

72 HOURS, specimen stored wet or dry;

TWO WEEKS, specimen stored wet or dry.

Initial measurements for Design D research casts were made with the .060" clear resin sheet vacuum-adapted to each cast. Initial measurements for Design E research casts were made with two thicknesses of baseplate wax adapted to each cast.

All measurements were made by the same investigator with the linear measuring microscope in the Biomaterials Research Laboratory, UTHSC at San Antonio Dental School. Investigator accuracy was determined to be + or - 0.003 millimeters by making ten measurements of an object with a known length.

The following protocol was established for setting up the Gaertner linear measuring microscope for each series of measurements:

1) adjust heighth of traveling stage to predesignated mark,
2) adjust eyepiece to mid-range focus,
3) use level to orient traveling stage horizontally,
4) turn lamp to 6.75 illumination intensity.

The following protocol was established for alignment of the individual casts and specimens for each series of measurements:

1) utilize glass slab for base to be moved about on fixed stage,
2) place three spheres of Ti-cene clay in tripod design on glass slab,
3) undersurface of cast and/or specimen tripoded on spheres of Ti-cene clay,
4) orient tops of pindex pins to flat metal disk in paralleling device (B & R instrument),
5) use level to check horizontal orientation,
6) glass slab with tripoded cast and/or specimen taken to measuring microscope for measurements (see Plate 9).

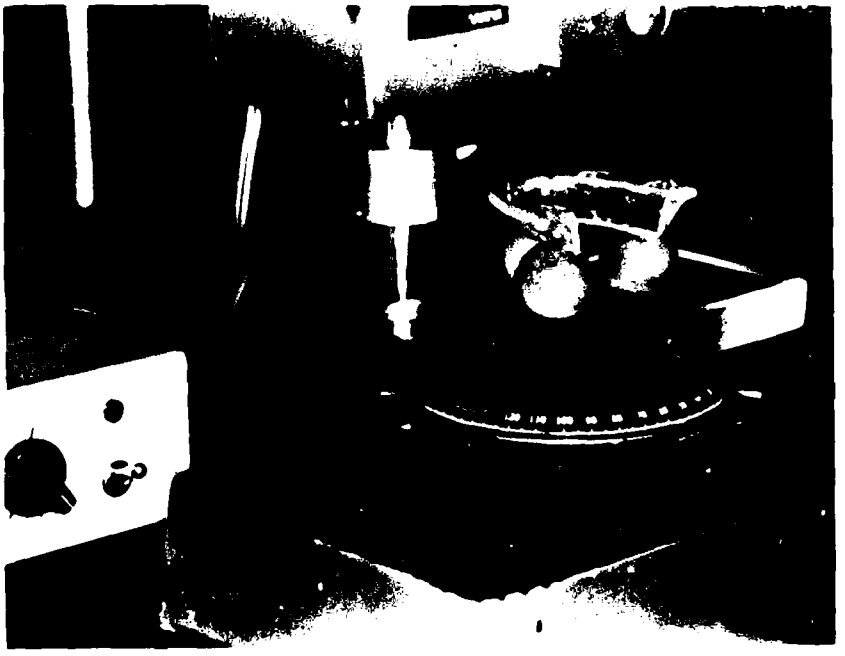
Record keeping procedures for data collection consisted of tables listing the design, specimen number, storage method, distance measured, and time intervals. All measurements made with the Gaertner linear measuring microscope were recorded to the nearest 0.001 millimeter.

F. Experimental Design and Statistical Analysis

Experimental Design

A four factor repeated measures experimental design was utilized for the present study. Factor 1, a random factor, was the fabrication techniques for specimens and contained five levels. Level 1 consisted of a one stage sprinkle-on technique (Design A). Level 2 consisted of a three stage sprinkle-on technique (Design B). Level 3 consisted of a dough application

Plate 9. Specimen tripoded on glass slab with spheres of Ti-cene clay for each series of measurements.



technique (Design C). Level 4 consisted of a vacuum-adapted resin sheet and dough application technique (Design D). Level 5 consisted of a wax-up and heat-cured technique (Design E). Factor 2, a random factor, was the storage methods for specimens and contained two levels. Level 1 consisted of a wet storage condition (Wet). Level 2 consisted of a dry storage condition (Dry). Factor 3, a random factor, was the locations of the measurements for specimens and contained four levels. Level 1 consisted of the location between reference points A and B (Location A-B). Level 2 consisted of the location between reference points C and D (Location C-D). Level 3 consisted of the location between reference points A and C (Location A-C). Level 4 consisted of the location between reference points B and D (Location B-D). Factor 4, a repeated factor, was the assessment time periods for the specimens and contained five levels. Level 1 consisted of the on cast measurement minus the initial measurement (Time 1). Level 2 consisted of the zero hour measurement minus the initial measurement (Time 2). Level 3 consisted of the 24 hour measurement minus the initial measurement (Time 3). Level 4 consisted of the 72 hour measurement minus the initial measurement (Time 4). Level 5 consisted of the two week measurement minus the initial measurement (Time 5).

The dependent measure was linear dimensional change as measured by subtracting the initial measurement from the measurement at each time period.

Statistical Analysis

A four factor repeated measures analysis of variance was used to calculate the overall F-ratio. In the case of significant interactions, appropriate tests of simple main effects using two way and single factor partitioning of variance were performed. All multiple pairwise comparisons were assessed using the Scheffe F-ratio test. The level of significance was established at .05.

V. RESULTS

The means and standard deviations of cumulative linear dimensional change across designs, conditions, locations, and time are summarized in Table 1. It can be seen that the mean cumulative linear dimensional change for all designs at Time 5 at location C-D appear greater than at locations A-B, A-C, and B-D, except for Design A under Dry Condition and Design E under Wet Condition. It can also be seen that the mean cumulative linear dimensional change for all designs at Time 5 at location A-B appear greater than at locations A-C and B-D, except for Designs A and C under Dry Condition and Designs A and B under Wet Condition.

It appears that the wet storage method resulted in less cumulative linear dimensional change for each design at each location at Time 5 than the dry storage method, except Design A at Location C-D (see Table 1).

It appears that the Design A fabrication technique provided for the least cumulative linear dimensional change over the measured time periods and that the Design D fabrication technique provided for the greatest cumulative linear dimensional change over the measured time periods (see Table 1).

The summary of the four factor repeated measures analysis of variance is listed in Table 2. It should be noted that the linear dimensional change significantly differed across the different designs ($p < .001$), as well as, across the storage

TABLE 1. STATISTICAL MEANS AND STANDARD DEVIATIONS OF CUMULATIVE LINEAR DIMENSIONAL CHANGE

All values are in millimeters (mm).

DRY CONDITION

REPEATED MEASURES

	Time 1	Time 2	Time 3	Time 4	Time 5
Design A					
A-B	-.002 (.017)	-.050 (.090)	-.040 (.022)	-.057 (.023)	-.069 (.034)
C-D	-.002 (.020)	-.057 (.025)	-.039 (.035)	-.036 (.045)	-.031 (.070)
A-C	-.029 (.030)	-.062 (.030)	-.078 (.024)	-.085 (.029)	-.105 (.027)
B-D	-.029 (.024)	-.059 (.012)	-.077 (.019)	-.085 (.013)	-.102 (.027)
Design B					
A-B	-.013 (.022)	-.069 (.025)	-.087 (.021)	-.106 (.028)	-.127 (.034)
C-D	-.002 (.014)	-.074 (.032)	-.097 (.036)	-.115 (.051)	-.140 (.045)
A-C	-.025 (.014)	-.056 (.010)	-.076 (.010)	-.091 (.013)	-.102 (.013)
B-D	-.005 (.015)	-.038 (.011)	-.066 (.051)	-.072 (.014)	-.081 (.014)
Design C					
A-B	-.059 (.075)	-.148 (.060)	-.151 (.056)	-.160 (.062)	-.153 (.056)
C-D	-.084 (.046)	-.280 (.085)	-.269 (.143)	-.261 (.155)	-.215 (.144)
A-C	-.153 (.038)	-.168 (.040)	-.179 (.038)	-.183 (.042)	-.188 (.042)
B-D	-.096 (.066)	-.147 (.036)	-.146 (.044)	-.159 (.042)	-.162 (.037)
Design D					
A-B	-.145 (.049)	-.214 (.062)	-.246 (.072)	-.266 (.090)	-.278 (.093)
C-D	-.093 (.030)	-.305 (.095)	-.426 (.153)	-.458 (.168)	-.468 (.176)
A-C	-.160 (.047)	-.162 (.039)	-.166 (.041)	-.175 (.042)	-.184 (.043)
B-D	-.118 (.026)	-.147 (.063)	-.129 (.030)	-.136 (.036)	-.141 (.025)
Design E					
A-B	-.061 (.080)	-.152 (.085)	-.162 (.090)	-.168 (.085)	-.196 (.080)
C-D	-.037 (.027)	-.227 (.059)	-.229 (.066)	-.236 (.065)	-.269 (.095)
A-D	-.107 (.039)	-.100 (.031)	-.107 (.027)	-.124 (.029)	-. 51 (.027)
B-D	-.075 (.044)	-.078 (.043)	-.089 (.041)	-.101 (.044)	-.129 (.040)

TABLE 1 (con't). STATISTICAL MEANS AND STANDARD DEVIATIONS OF CUMULATIVE LINEAR DIMENSIONAL CHANGE

All values are in millimeters (mm).

WET CONDITION

REPEATED MEASURES

	Time 1	Time 2	Time 3	Time 4	Time 5
Design A					
A-B	+.018 (.030)	-.015 (.046)	-.019 (.012)	+.006 (.027)	+.043 (.025)
C-D	-.007 (.012)	-.066 (.029)	-.032 (.076)	+.010 (.076)	+.097 (.075)
A-C	-.021 (.006)	-.048 (.011)	-.060 (.017)	-.046 (.006)	-.043 (.007)
B-D	-.038 (.014)	-.068 (.016)	-.069 (.006)	-.067 (.016)	-.063 (.012)
Design B					
A-B	-.016 (.022)	-.080 (.022)	-.078 (.029)	-.074 (.044)	-.052 (.038)
C-D	-.016 (.014)	-.115 (.045)	-.144 (.067)	-.138 (.074)	-.074 (.056)
A-C	-.031 (.025)	-.065 (.017)	-.074 (.015)	-.074 (.020)	-.066 (.014)
B-D	-.013 (.017)	-.040 (.014)	-.051 (.018)	-.045 (.020)	-.042 (.015)
Design C					
A-B	-.069 (.060)	-.161 (.054)	-.176 (.043)	-.178 (.043)	-.126 (.059)
C-D	-.039 (.052)	-.239 (.053)	-.323 (.051)	-.341 (.055)	-.182 (.090)
A-C	-.095 (.081)	-.103 (.079)	-.100 (.078)	-.095 (.071)	-.076 (.070)
B-D	-.086 (.043)	-.101 (.033)	-.098 (.036)	-.100 (.034)	-.076 (.031)
Design D					
A-B	-.150 (.015)	-.198 (.046)	-.228 (.048)	-.225 (.054)	-.184 (.060)
C-D	-.075 (.022)	-.242 (.085)	-.378 (.119)	-.430 (.118)	-.352 (.101)
A-C	-.119 (.026)	-.127 (.033)	-.127 (.027)	-.127 (.038)	-.103 (.031)
B-D	-.105 (.025)	-.112 (.038)	-.106 (.033)	-.100 (.024)	-.087 (.030)
Design E					
A-B	-.070 (.043)	-.156 (.033)	-.164 (.031)	-.163 (.036)	-.145 (.036)
C-D	+.001 (.034)	-.145 (.069)	-.116 (.062)	-.164 (.061)	-.128 (.047)
A-C	-.054 (.072)	-.063 (.060)	-.065 (.068)	-.067 (.063)	-.059 (.065)
B-D	-.046 (.045)	-.062 (.050)	-.054 (.059)	-.065 (.051)	-.058 (.051)

TABLE 1 (con't). STATISTICAL MEANS AND STANDARD DEVIATIONS OF CUMULATIVE LINEAR DIMENSIONAL CHANGE

All values are in millimeters (mm).

ALL SPECIMENS

REPEATED MEASURES

	Time 1	Time 2	Time 3	Time 4	Time 5
Design A					
A-B	+.010 (.024)	-.032 (.036)	-.030 (.020)	-.026 (.041)	-.013 (.065)
C-D	-.001 (.016)	-.061 (.056)	-.035 (.056)	-.013 (.063)	+.033 (.096)
A-C	-.025 (.021)	-.055 (.023)	-.069 (.022)	-.066 (.029)	-.077 (.035)
B-D	-.033 (.021)	-.063 (.014)	-.073 (.014)	-.076 (.017)	-.083 (.023)
Design B					
A-B	-.014 (.021)	-.074 (.023)	-.082 (.024)	-.090 (.039)	-.089 (.052)
C-D	-.009 (.015)	-.095 (.043)	-.121 (.056)	-.126 (.061)	-.107 (.059)
A-C	-.028 (.019)	-.060 (.014)	-.075 (.012)	-.082 (.018)	-.084 (.022)
B-D	-.009 (.016)	-.039 (.012)	-.054 (.013)	-.058 (.022)	-.061 (.025)
Design C					
A-B	-.064 (.064)	-.154 (.055)	-.163 (.049)	-.169 (.051)	-.140 (.056)
C-D	-.061 (.052)	-.260 (.070)	-.296 (.105)	-.301 (.117)	-.198 (.115)
A-C	-.124 (.067)	-.135 (.068)	-.139 (.071)	-.139 (.072)	-.132 (.081)
B-D	-.091 (.053)	-.124 (.040)	-.122 (.045)	-.129 (.048)	-.119 (.056)
Design D					
A-B	-.148 (.034)	-.206 (.052)	-.237 (.058)	-.246 (.073)	-.231 (.089)
C-D	-.084 (.026)	-.273 (.091)	-.402 (.132)	-.444 (.138)	-.410 (.149)
A-C	-.139 (.042)	-.144 (.039)	-.147 (.039)	-.151 (.045)	-.143 (.055)
B-D	-.111 (.025)	-.129 (.052)	-.117 (.033)	-.118 (.035)	-.114 (.039)
Design E					
A-B	-.065 (.061)	-.154 (.061)	-.163 (.064)	-.165 (.062)	-.170 (.064)
C-D	-.018 (.035)	-.186 (.074)	-.197 (.069)	-.200 (.070)	-.198 (.103)
A-C	-.081 (.061)	-.082 (.049)	-.086 (.054)	-.096 (.055)	-.105 (.067)
B-D	-.061 (.045)	-.070 (.045)	-.072 (.051)	-.083 (.049)	-.093 (.057)

TABLE 2. SUMMARY TABLE FOR FOUR FACTOR REPEATED MEASURES ANALYSIS OF VARIANCE (ANOVA)

Source:	df:	SS:	MS:	F-test:	P-value:
DESIGN (A)	4	3.312	.828	67.376	.0001*
CONDITION (B)	1	.240	.240	19.541	.0001*
A x B	4	.045	.011	.912	.4587
LOCATION (C)	3	.872	.291	23.663	.0001*
A x C	12	1.129	.094	7.655	.0001*
B x C	3	.018	.006	.491	.6888
A x B x C	12	.107	.009	.723	.7276
subjects with groups	160	1.966	.012		
TIME PERIODS (D)	4	.872	.218	355.377	.0001*
A x D	16	.155	.010	15.765	.0001*
B x D	4	.130	.033	53.153	.0001*
A x B x D	16	.016	.001	1.599	.0638
C x D	760	.522	.044	70.953	.0001*
A x C x D	48	.483	.010	16.417	.0001*
B x C x D	12	.025	.002	3.351	.0001*
A x B x C x D	48	.039	.001	1.315	.0800
D x subjects with groups	640	.393	.001		

* denotes significance at $p < .05$

conditions ($p < .001$). In addition, there were significant differences in linear dimensional change across the different locations ($p < .001$), as well as, across the different time periods ($p < .001$). Due to significant interactions between design, location, and time ($p < .001$), condition, location, and time ($p < .001$), as well as, design and location ($p < .001$), design and time ($p < .001$), condition and time ($p < .001$), and location and time ($p < .001$), these significant effects are only important when considering them with respect to each other. Thus, simple main effects tests were performed. The summary of these analyses can be seen in Tables 3, 4, and 5.

Significant differences existed between design and location across each of the time periods at $p < .05$ (see Table 3). One-factor analyses of variances were performed to test for simple, simple main effects (see Table 4). Multiple pairwise comparisons of designs at each location at each time interval were analyzed. The summary of these multiple pairwise comparison analyses can be seen in Table 6. Statistically significant subsets ($p < .05$) are underlined and listed in order of increasing dimensional change, left to right.

Multiple pairwise comparison analyses of each Design at Location A-B at Time 1 (On Cast - Initial Measurement) revealed that the linear dimensional change of Design A was significantly less than those of Designs C, D, and E ($p < .05$). Similar analysis revealed that the linear dimensional changes of Designs

TABLE 3. SUMMARY TABLE FOR SIMPLE MAIN EFFECTS OF DESIGN x LOCATION x TIME

(ANOVA Tables for 2-Factor Analysis of Variance)

Source:	df:	SS:	MS:	F-test:	P-value:
TIME 1					
DESIGN (A)	4	.05.	.017	10.554	.0001*
LOCATION (B)	3	.343	.086	53.527	.0001*
A x B	12	.036	.003	1.886	.0386*
Error	180	.288	.002	--	--
TIME 2					
DESIGN (A)	4	.571	.143	58.996	.0001*
LOCATION (B)	3	.244	.081	33.552	.0001*
A x B	12	.119	.010	4.109	.0001*
Error	180	.435	.002	--	--
TIME 3					
DESIGN (A)	4	.796	.199	59.810	.0001*
LOCATION (B)	3	.446	.149	44.716	.0001*
A x B	12	.382	.032	9.574	.0001*
Error	180	.599	.032	--	--
TIME 4					
DESIGN (A)	4	.941	.235	59.965	.0001*
LOCATION (B)	3	.461	.154	39.198	.0001*
A x B	12	.519	.043	11.025	.0001*
Error	180	.706	.004	--	--
TIME 5					
DESIGN (A)	4	.816	.204	38.674	.0001*
LOCATION (B)	3	.193	.064	12.180	.0001*
A x B	12	.555	.046	8.777	.0001*
Error	180	.949	.005	--	--

* denotes significance at $p < .05$

TABLE 4. SUMMARY TABLE FOR SIMPLE, SIMPLE MAIN EFFECTS OF DESIGN x LOCATION x TIME

(ANOVA Tables for One-Factor Analysis of Variance)

Source:	df:	SS:	MS:	F-test:	P-value:
TIME 1					
DESIGN x LOC AB					
Between groups	4	.146	.037	18.256	.0001*
Within groups	45	.090	.002	--	--
Total	49	.236	--	--	--
DESIGN x LOC CD					
Between groups	4	.052	.013	12.832	.0001*
Within groups	45	.046	.001	--	--
Total	49	.098	--	--	--
DESIGN x LOC AC					
Between groups	4	.112	.028	12.882	.0001*
Within groups	45	.097	.002	--	--
Total	49	.209	--	--	--
DESIGN x LOC BD					
Between groups	4	.069	.017	14.156	.0001*
Within groups	45	.055	--	--	--
Total	49	.125	--	--	--
TIME 2					
DESIGN x LOC AB					
Between groups	4	.193	.048	21.466	.0001*
Within groups	45	.101	.002	--	--
Total	49	.294	--	--	--
DESIGN x LOC CD					
Between groups	4	.364	.091	21.429	.0001*
Within groups	45	.191	.004	--	--
Total	49	.555	--	--	--
DESIGN x LOC AC					
Between groups	4	.071	.018	9.531	.0001*
Within groups	45	.083	.002	--	--
Total	49	.154	--	--	--
DESIGN x LOC BD					
Between groups	4	.063	.016	11.785	.0001*
Within groups	45	.060	.001	--	--
Total	49	.123	--	--	--

TABLE 4 (con't). SUMMARY TABLE FOR SIMPLE, SIMPLE MAIN EFFECTS OF DESIGN x LOCATION x TIME

(ANOVA Tables for One-Factor Analysis of Variance)

Source:	df:	SS:	MS:	F-test:	P-value:
TIME 3					
DESIGN x LOC AB					
Between groups	4	.259	.065	29.829	.0001*
Within groups	45	.098	.002	--	--
Total	49	.356	--	--	--
DESIGN x LOC CD					
Between groups	4	.829	.207	26.219	.0001*
Within groups	45	.356	.008	--	--
Total	49	1.185	--	--	--
DESIGN x LOC AC					
Between groups	4	.054	.014	6.712	.0003*
Within groups	45	.091	.002	--	--
Total	49	.145	--	--	--
DESIGN x LOC BD					
Between groups	4	.036	.009	7.430	.0001*
Within groups	45	.055	.001	--	--
Total	49	.091	--	--	--
TIME 4					
DESIGN x LOC AB					
Between groups	4	.282	.071	23.580	.0001*
Within groups	45	.135	.003	--	--
Total	49	.417	--	--	--
DESIGN x LOC CD					
Between groups	4	1.088	.272	29.971	.0001*
Within groups	45	.409	.009	--	--
Total	49	1.497	--	--	--
DESIGN x LOC AC					
Between groups	4	.054	.014	5.920	.0001*
Within groups	45	.103	.002	--	--
Total	49	.158	--	--	--
DESIGN x LOC BD					
Between groups	4	.035	.009	6.607	.0001*
Within groups	45	.060	.001	--	--
Total	49	.095	--	--	--

TABLE 4 (con't). SUMMARY TABLE FOR SIMPLE, SIMPLE MAIN EFFECTS OF DESIGN x LOCATION x TIME

(ANOVA Tables for One-Factor Analysis of Variance)

Source:	df:	SS:	MS:	F-test:	P-value:
TIME 5					
DESIGN x LOC AB					
Between groups	4	.273	.068	15.420	.0001*
Within groups	45	.199	.004	--	--
Total	49	.472	--	--	--
DESIGN x LOC CD					
Between groups	4	1.042	.260	22.284	.0001*
Within groups	45	.526	.012	--	--
Total	49	1.568	--	--	--
DESIGN x LOC AC					
Between groups	4	.034	.008	2.666	.0443*
Within groups	45	.143	.003	--	--
Total	49	.176	--	--	--
DESIGN x LOC BD					
Between groups	4	.022	.006	3.075	.0254*
Within groups	45	.081	.002	--	--
Total	49	.103	--	--	--

* denotes significance at $p < .05$

TABLE 5. SUMMARY TABLE FOR SIMPLE MAIN EFFECTS OF CONDITION x LOCATION x TIME

(ANOVA Tables for 2-Factor Analysis of Variance)

Source:	df:	SS:	MS:	F-test:	P-value:
TIME 1					
CONDITION (A)	1	.009	.009	2.629	.1066
LOCATION (B)	3	.051	.017	4.985	.0024*
A x B	3	.008	.003	.743	.5276
Error	192	.051	.003	--	--
TIME 2					
CONDITION (A)	1	.019	.019	3.305	.0706
LOCATION (B)	3	.244	.081	14.141	.0001*
A x B	3	.005	.002	.267	.8494
Error	192	1.102	.006	--	--
TIME 3					
CONDITION (A)	1	.015	.015	1.618	.2049
LOCATION (B)	3	.446	.149	16.296	.0001*
A x B	3	.009	.003	.345	.7930
Error	192	1.754	.009	--	--
TIME 4					
CONDITION (A)	1	.044	.044	3.969	.0478*
LOCATION (B)	3	.461	.154	13.986	.0001*
A x B	3	.011	.004	.347	.7913
Error	192	2.111	.011	--	--
TIME 5					
CONDITION (A)	1	.284	.284	26.940	.0001*
LOCATION (B)	3	.193	.064	6.086	.0006*
A x B	3	.010	.003	.308	.8198
Error	192	2.026	.011	--	--

* denotes significance at $p < .05$

TABLE 6. SUMMARY TABLE FOR MULTIPLE PAIRWISE COMPARISON ANALYSES OF DESIGN

REPEATED MEASURES

	Time 1	Time 2	Time 3	Time 4	Time 5
Location A-B	A B C E D	A B C E D	A B C E D	A B C E D	A B C E D
Location C-D	A B E C D	A B E C D	A B E C D	A B E C D	A B C E D
Location A-C	A B E C D	A B E C D	A B E C D	A B E C D	A B E C D
Location B-D	B A E C D	B A E C D	B E A D C	B A E D C	B A E D C

*Underline denotes statistically significant subsets listed in order of increasing dimensional change, left to right, at $p < .05$.

B, C, and E were significantly less than that of Design D ($p < .05$).

Multiple pairwise comparison analyses of each Design at Location C-D at Time 1 revealed that the linear dimensional changes of Design A and Design B were significantly less than those of Designs C and D ($p < .05$). Similar analysis revealed that the linear dimensional change of Design E was significantly less than that of Design D.

Multiple pairwise comparison analyses of each Design at Location A-C at Time 1 revealed that the linear dimensional changes of Design A and Design B were significantly less than those of Design C and D ($p < .05$).

Multiple pairwise comparison analyses of each Design at Location B-D at Time 1 revealed that the linear dimensional changes of Design A and Design B were significantly less than those of Designs C and D ($p < .05$). Similar analysis revealed that the linear dimensional change of Design B was significantly less than that of Design E ($p < .05$), and that Design E linear dimensional change was significantly less than that of Design D ($p < .05$).

Multiple pairwise comparison analyses of each Design at Location A-B at Time 2 (0 Hour - Initial Measurement) revealed that the linear dimensional changes of Design A and Design B were significantly less than those of Designs C, D, and E ($p < .05$).

Multiple pairwise comparison analyses of each Design at Location C-D at Time 2 revealed that the linear dimensional

change of Design A was significantly less than those of Designs C, D, and E ($p < .05$). Similar analysis revealed that the linear dimensional change of Design B was significantly less than those of Designs C and D ($p < .05$).

Multiple pairwise comparison analyses of each design at Location A-C at Time 2 revealed that the linear dimensional changes of Design A and Design B were significantly less than those of Designs C and D ($p < .05$). Similar analysis revealed that the linear dimensional change of Design E was significantly less than Design D ($p < .05$).

Multiple pairwise comparison analyses of each design at Location B-D at Time 2 revealed that the linear dimensional changes of Design A and Design B were significantly less than those of Designs C and D ($p < .05$). Similar analysis revealed that the linear dimensional change of Design E was also significantly less than those of Designs C and D ($p < .05$).

Multiple pairwise comparison analyses of each design at Location A-B at Time 3 (24 Hour - Initial Measurement) revealed that the linear dimensional change of Design A and Design B were significantly less than those of Designs C, D, and E ($p < .05$). Similar analysis revealed that the linear dimensional changes of Design C and Design E were significantly less than Design D ($p < .05$).

Multiple pairwise comparison analyses of each design at Location C-D at Time 3 revealed that the linear dimensional change of Design A was significantly less than those of Designs

C, D and E ($p < .05$). Similar analysis revealed that the linear dimensional change of Design B was significantly less than those of Designs C and D ($p < .05$), and that of Design E was significantly less than that of Design D ($p < .05$).

Multiple pairwise comparison analyses of each design at Location A-C at Time 3 revealed that the linear dimensional change of Design A was significantly less than those of Designs C and D ($p < .05$). Similar analysis revealed that the linear dimensional change of Design B was significantly less than that of Design D ($p < .05$).

Multiple pairwise comparison analyses of each design at Location B-C at Time 3 revealed that the linear dimensional change of Design A was significantly less than those of Designs C and D ($p < .05$). Similar analysis revealed that the linear dimensional change of Design B was significantly less than Design D ($p < .05$).

Multiple pairwise comparison analyses of each design at Location A-C at Time 4 (Initial Measurement) revealed that the linear dimensional change of Design A was significantly less than those of Designs C and D ($p < .05$). Similar analysis revealed that the linear dimensional change of Design B was significantly less than those of Designs C and D ($p < .05$); and that of Design E was significantly less than that of Design D ($p < .05$).

Multiple pairwise comparison analyses of each design at Location B-C at Time 4 revealed that the linear dimensional

AD-A185 891 THE EFFECTS OF FABRICATION TECHNIQUES AND STORAGE METHODS ON THE DIMENSIO..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH D M BOHNENKAMP MAY 87 2/2

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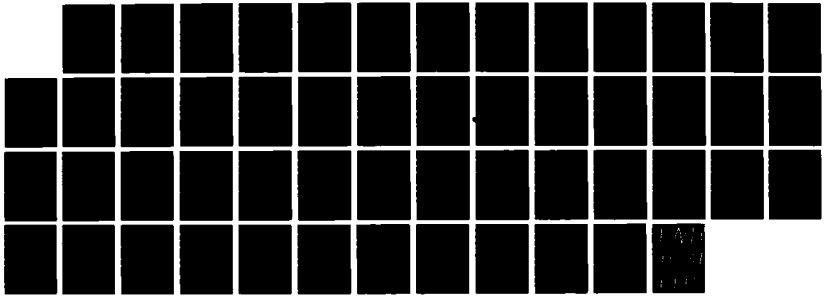
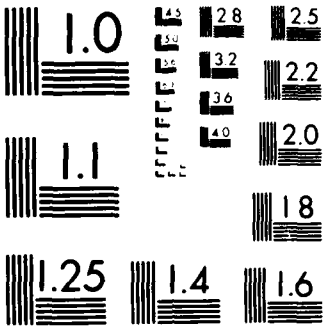




change of Design A was significantly less than those of Design C, D, and E ($p < .05$). Similar analysis revealed that the linear dimensional change of Design B was significantly less than those of Designs C and D ($p < .05$); and those of Design C and Design E were significantly less than that of Design D.

Multiple pairwise comparison analyses of each design at Location A-C at Time 4 revealed that the linear dimensional change of Design A was significantly less than Designs C and D ($p < .05$). Similar analysis revealed that the linear dimensional change of Design B was significantly less than that of Design D ($p < .05$).

Multiple pairwise comparison analyses of each design at Location B-D at Time 4 revealed that the linear dimensional change of Design A was significantly less than than of Design C ($p < .05$). Similar analysis revealed that the linear dimensional change of Design B was significantly less than those of Designs C and D ($p < .05$).

Multiple pairwise comparison analyses of each design at Location A-B at Time 5 (Two Week - Initial Measurement) revealed that the linear dimensional change of Design A was significantly less than those of Designs C, D, and E ($p < .05$). Similar analysis revealed that the linear dimensional change of Design B was significantly less than that of Design D ($p < .05$).

Multiple pairwise comparison analyses of each design at Location C-D at Time 5 revealed that the linear dimensional change of Design A was significantly less than those of Designs

C, D, and E ($p < .05$). Similar analysis revealed that the linear dimensional changes of Design B, Design C, and Design E were significantly less than that of Design D ($p < .05$).

Multiple pairwise comparison analyses of each design at Location A-C at Time 5 revealed no significant differences in linear dimensional changes between any of the designs ($p < .05$).

Multiple pairwise comparison analyses of each design at Location B-D at Time 5 revealed no significant differences in linear dimensional changes between any of the designs ($p < .05$).

No significant interactions existed between storage condition and location across any of the time periods at $p < .05$ (see Table 5). However, it can be seen that significant differences existed for storage condition across two of the time periods at $p < .05$, and for location across all of the time periods at $p < .05$ (see Table 5).

Pairwise comparison analysis of storage condition at Time 4 (72 Hour minus Initial Measurement) revealed that specimens stored in a wet environment demonstrated less linear dimensional change than specimens stored in a dry environment ($p < .05$).

A similar pairwise comparison analysis of storage condition at Time 5 (Two Week minus Initial Measurement) revealed that specimens stored in a wet environment demonstrated significantly less linear dimensional change than specimens stored in a dry environment ($p < .05$).

Multiple pairwise comparison analyses of each location at Time 1 (On Cast minus Initial Measurement) revealed that the

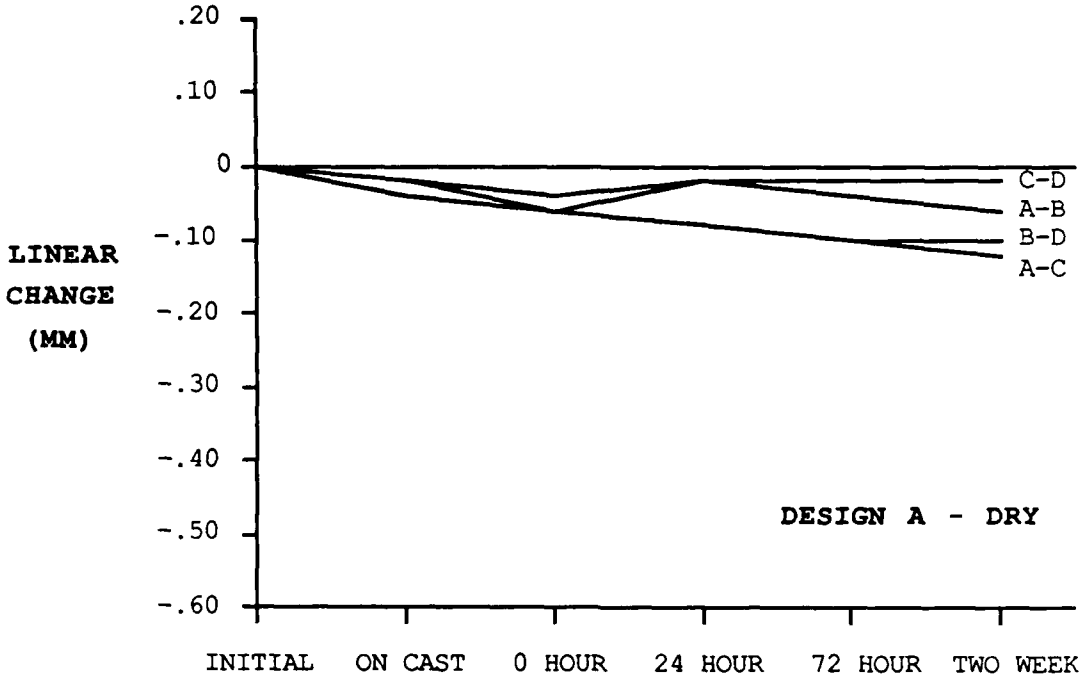
linear dimensional change at Location C-D was significantly greater than that at Location A-C ($p < .05$).

Multiple pairwise comparison analyses of each location at Time 2 (0 Hour minus Initial Measurement), Time 3 (24 Hour minus Initial Measurement), and Time 4 (72 Hour minus Initial Measurement) revealed that the linear dimensional change at Location C-D was significantly greater than those at Locations A-B, A-C, and B-D ($p < .05$).

Multiple pairwise comparison analyses of each location at Time 5 (Two Week minus Initial Measurement) revealed that the linear dimensional change at Location C-D was significantly greater than those at Locations A-C and B-D ($p < .05$).

The statistical means for specimens stored in either a wet or dry condition (see Table 1) were computed and plotted in linear graph form. The line graphs (Figs. 1-5) provide a composite view of the cumulative linear dimensional changes for fabrication techniques and storage methods at the four locations across the time periods. The line graphs appear to show the range in dimensional stability of the different fabrication techniques and storage methods and to provide an indication of variation with time for the individual designs and storage conditions.

Figure 1. Line graphs of linear dimensional change of Design A for Dry versus Wet storage condition. Statistical means plotted for each location across time periods.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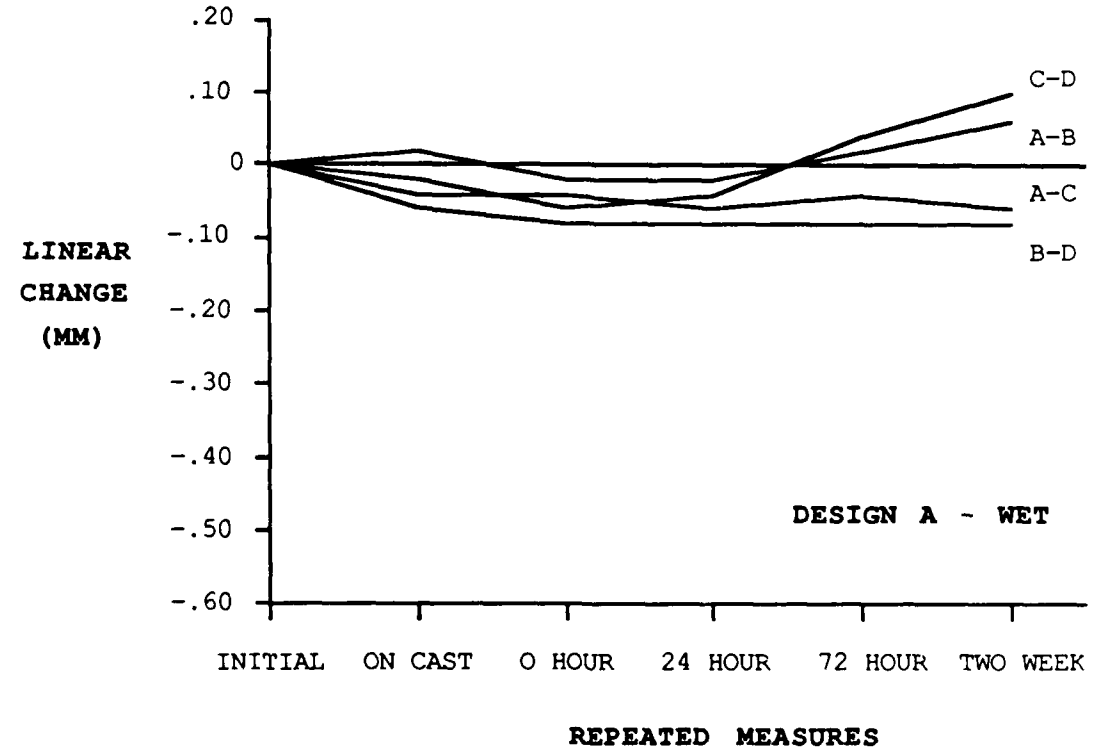
.10
0
-.10
-.20
-.30
-.40
-.50
-.60
LINEAR CHANGE (MM)
C-D
A-B
B-D
A-C
DESIGN A - DRY
INITIAL
ON CAST
0 HOUR
24 HOUR
72 HOUR
TWO WEEK
REPEATED MEASURES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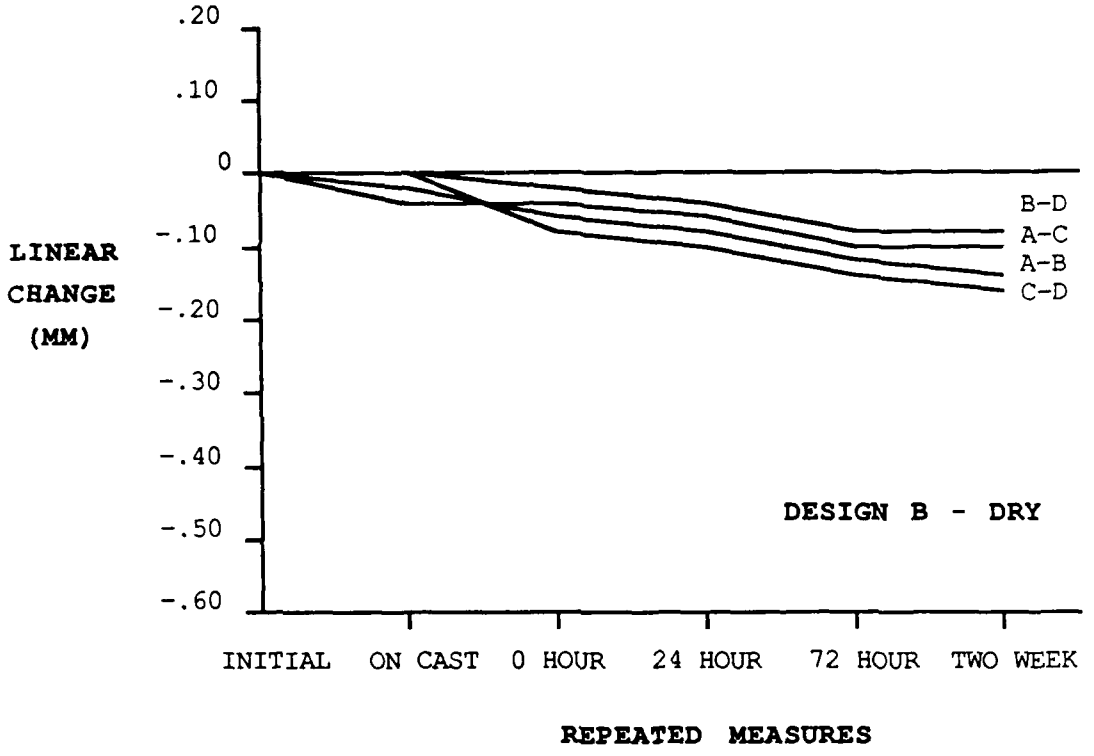
-.40
-.50
-.60
LINEAR CHANGE (MM)
C-D
A-B
A-C
B-D
DESIGN A - WET
INITIAL
ON CAST
0 HOUR
24 HOUR
72 HOUR
TWO WEEK
REPEATED MEASURES

Figure 2. Line graphs of linear dimensional change of Design B for Dry versus Wet storage condition. Statistical means plotted for each location across time periods.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.10
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-.20
-.30
-.40
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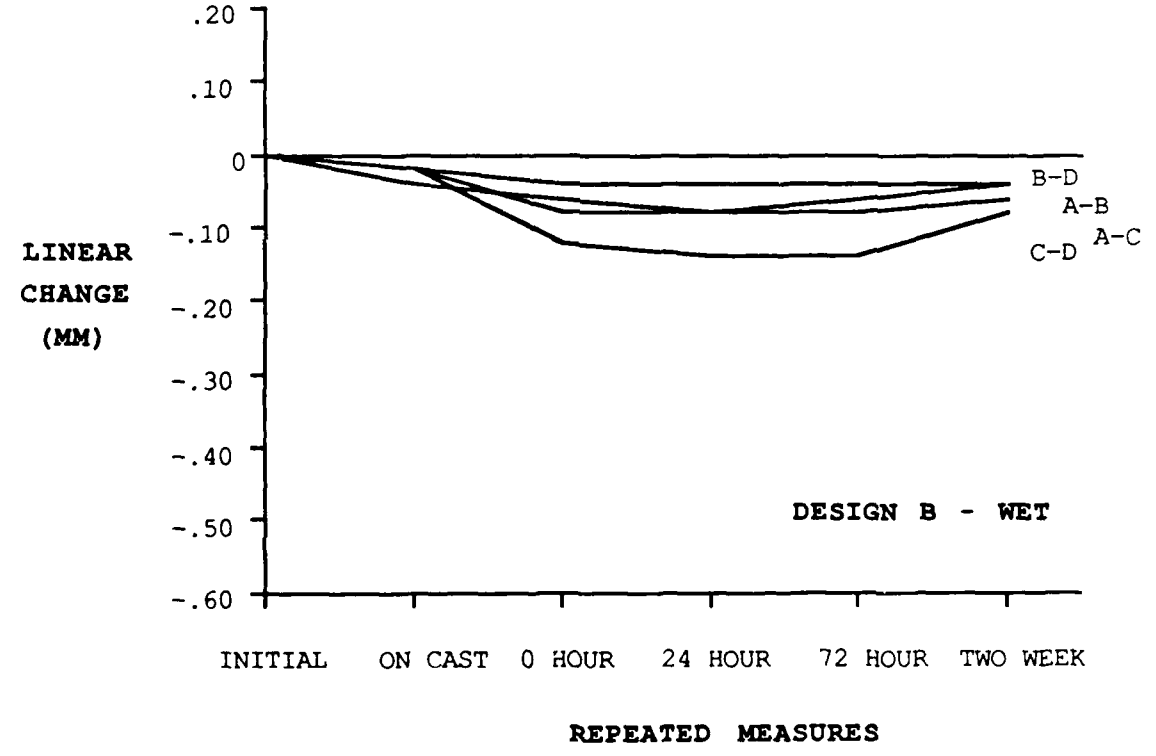
LINEAR CHANGE (MM)
B-D
A-C
A-B
C-D
DESIGN B - DRY
INITIAL
ON CAST
0 HOUR
24 HOUR
72 HOUR
TWO WEEK
REPEATED MEASURES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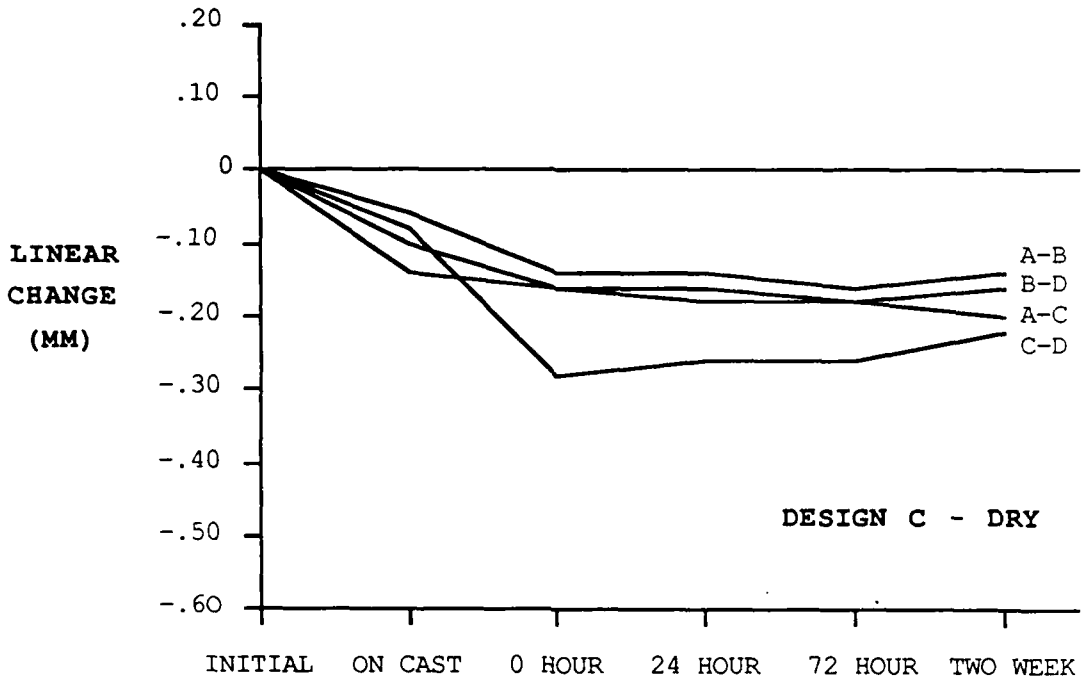
-.20
-.30
-.40
-.50
-.60
LINEAR CHANGE (MM)
B-D
A-B
A-C
C-D
DESIGN B - WET
INITIAL
ON CAST
0 HOUR
24 HOUR
72 HOUR
TWO WEEK
REPEATED MEASURES

Figure 3. Line graphs of linear dimensional change of Design C for Dry versus Wet storage condition. Statistical means plotted for each location across time periods.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.10
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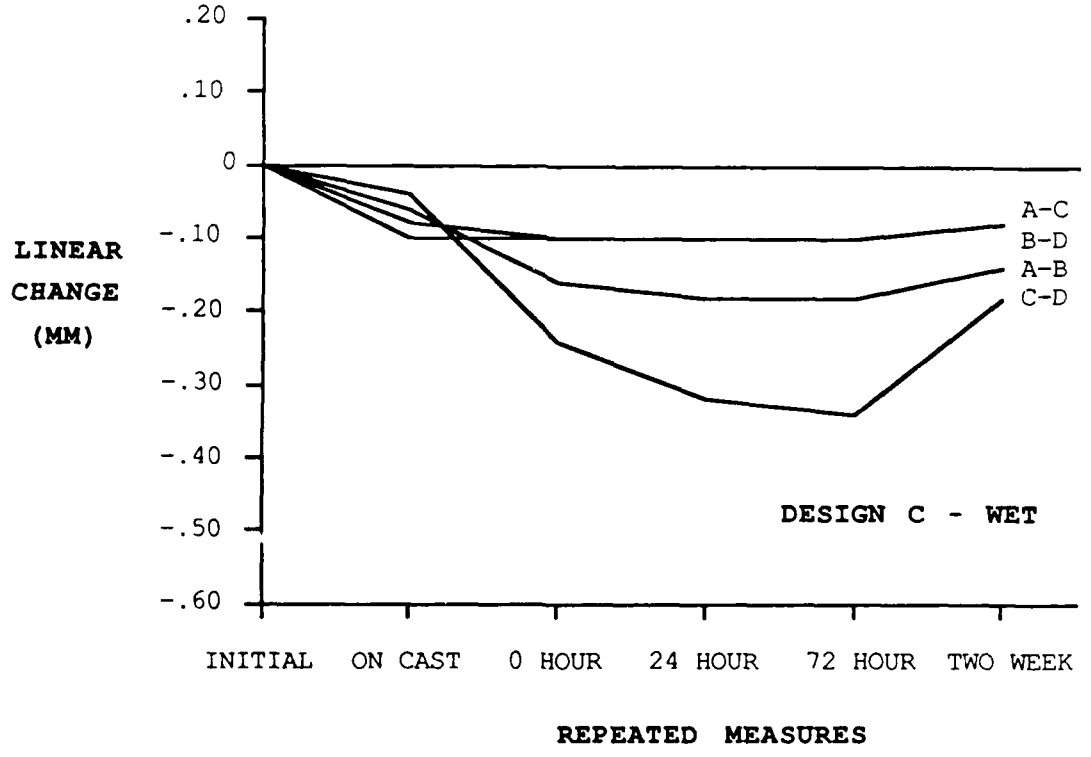
-.10
-.20
-.30
-.40
-.50
-.60
LINEAR CHANGE (MM)
A-B
B-D
A-C
C-D
DESIGN C - DRY
INITIAL
ON CAST
0 HOUR
24 HOUR
72 HOUR
TWO WEEK
REPEATED MEASURES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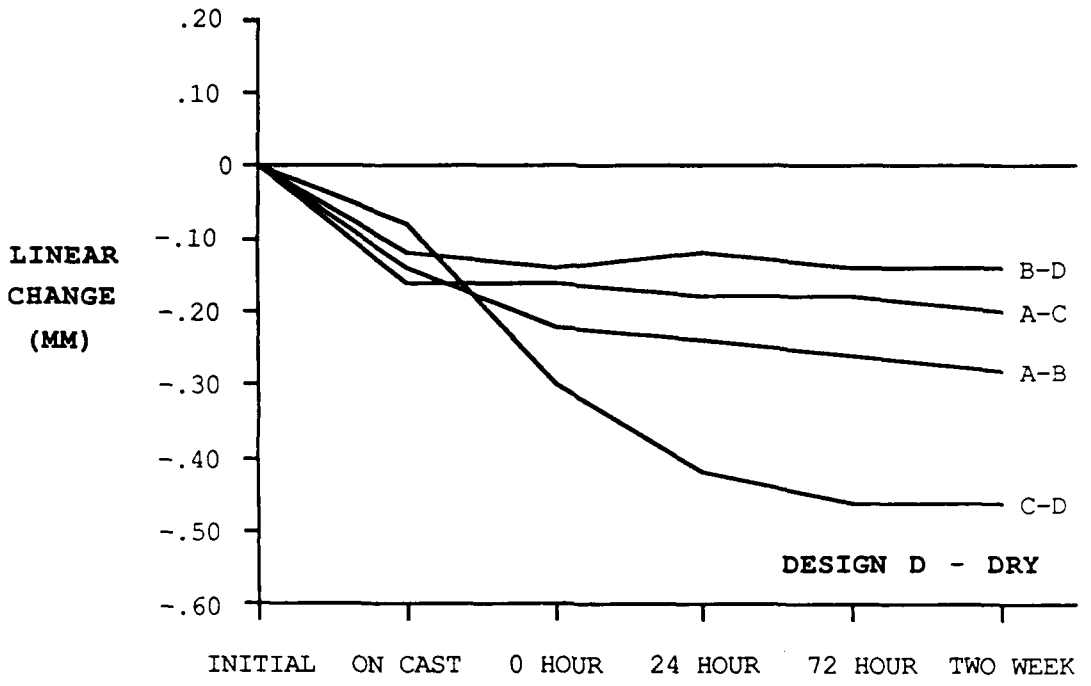
-.30
-.40
-.50
-.60
LINEAR CHANGE (MM)
A-C
B-D
A-B
C-D
DESIGN C - WET
INITIAL
ON CAST
0 HOUR
24 HOUR
72 HOUR
TWO WEEK
REPEATED MEASURES

Figure 4. Line graphs of linear dimensional change of Design D for Dry versus Wet storage condition. Statistical means plotted for each location across time periods.


.20
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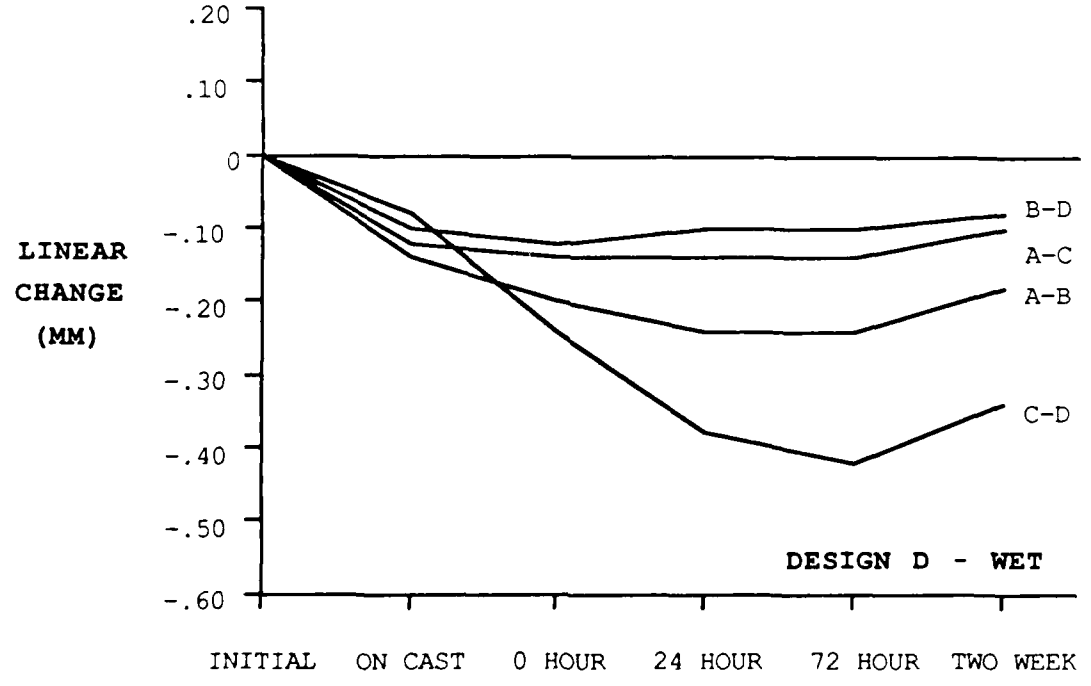
LINEAR CHANGE (MM)
B-D
A-C
A-B
C-D
DESIGN D - DRY
INITIAL
ON CAST
0 HOUR
24 HOUR
72 HOUR
TWO WEEK
REPEATED MEASURES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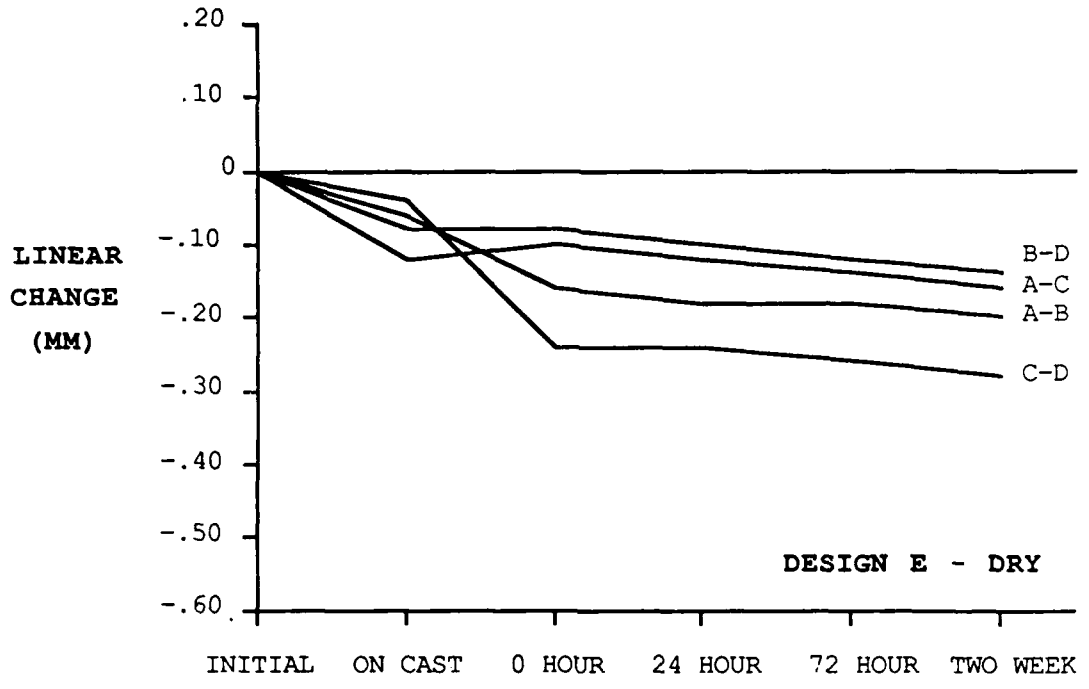
-.40
-.50
-.60
LINEAR CHANGE (MM)
B-D
A-C
A-B
C-D
DESIGN D - WET
INITIAL
ON CAST
0 HOUR
24 HOUR
72 HOUR
TWO WEEK
REPEATED MEASURES

Figure 5. Line graphs of linear dimensional change of Design E for Dry versus Wet storage condition. Statistical means plotted for each location across time periods.


.20
.10
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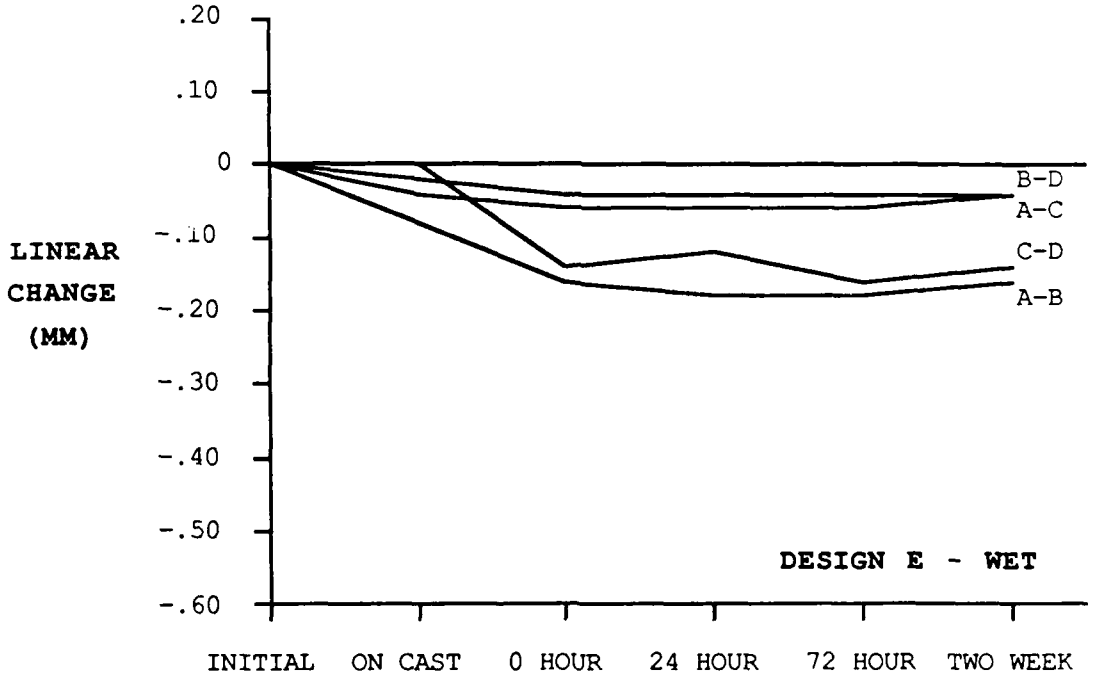
-.40
-.50
-.60
LINEAR CHANGE (MM)
B-D
A-C
A-B
C-D
DESIGN E - DRY
INITIAL
ON CAST
0 HOUR
24 HOUR
72 HOUR
TWO WEEK
REPEATED MEASURES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-.40
-.50
-.60
LINEAR CHANGE (MM)
B-D
A-C
C-D
A-B
DESIGN E - WET
INITIAL
ON CAST
0 HOUR
24 HOUR
72 HOUR
TWO WEEK
REPEATED MEASURES

VI. DISCUSSION

When an acrylic resin is employed in a situation requiring dimensional precision, one of the properties given first consideration is its stability. The accurate and precise fit of an orthosis in the mouth of a patient is of prime importance to the clinician. Consequently, any change in the dimensions of an orthosis, either during fabrication or prior to delivery to the patient, is of considerable importance. Since acrylic resins exhibit certain unavoidable dimensional changes, the clinician, as well as the laboratory technician, should understand the variables that can minimize inaccuracy of fit and subsequent distortion. These variables include, but are not limited to, construction materials, polymerization methods, fabrication techniques, and storage methods.

Recent comparisons of denture base acrylic resins (104,112), orthodontic base polymers (135), and autopolymerizing acrylic resin impression tray materials (39) have reported that different construction materials significantly affect dimensional stability. The materials utilized in these studies included autopolymerizing acrylic resins, heat-curing acrylic resins, and visible light-curing acrylic resins. The materials utilized in the present investigation were autopolymerizing acrylic resin (Design A, Design B, Design C), vacuum-adapted resin sheet and autopolymerizing acrylic resin (Design D), and heat-cured acrylic resin (Design E). Significant differences in linear dimensional

change at various time intervals were noted between fabrication techniques ($p < .05$) which utilized these various materials for construction. The autopolymerizing acrylic resin (if sprinkled-on) demonstrated less linear dimensional change than the heat-cured acrylic resin. This finding supports the results of other investigations (52,104,112). It would seem that, in light of the results of this study and others, the dimensional stability of removable acrylic resin orthoses may be influenced by the choice of materials utilized in the fabrication technique. Further research is indicated to determine if construction materials significantly affect the dimensional stability of acrylic resin orthoses.

Recent evaluations of polymerization methods for autopolymerizing and heat-cured acrylic resins (41,106,132) have observed that polymerization methods significantly affect dimensional stability. The polymerization methods involved in the fabrication techniques in the present study were bench-curing in air (Design A, Design B, and Design C), curing in water under air pressure (Design D), and heat-curing (Design E). Significant differences in linear dimensional change at various time intervals were noted between fabrication techniques ($p < .05$) which utilized these different polymerization methods during construction. The specimens bench-cured in air (except Design C) demonstrated less dimensional change than specimens heat-cured or cured in water under pressure. It would seem that, especially in light of the results observed in this study, the dimensional

stability of removable acrylic resin orthoses may be influenced by the choice of polymerization method utilized in the fabrication technique. Further research is indicated to determine if polymerization methods significantly affect the dimensional stability of acrylic resin orthoses.

Recent comparisons of denture base acrylic resins (104), and orthodontic base polymers (135) evaluated the dimensional stability of these materials while employing modified production techniques. The authors made no comparisons with regard to the significant effects of the modified production techinques. The fabrication techniques involved in the present study were autopolymerizing acrylic resin sprinkle-on additive techniques (Design A and Design B), autopolymerizing acrylic resin dough application technique (Design C), vacuum-adapted resin sheet and autopolymerizing acrylic resin dough application technique (Design D), and heat-cured acrylic resin denture processing technique (Design E). Significant differences in linear dimensional change at various time intervals were noted between designs which utilized these different fabrication techniques during construction ($p < .05$). The one-stage sprinkle-on technique demonstrated less dimensional change than the dough application technique, the vacuum-adapted resin sheet and dough application technique, and the heat-cured denture processing technique. It would seem that, especially in light of the findings of this investigaton, the dimensional stability of

removable acrylic resin orthoses may be strongly influenced by the choice of fabrication technique.

An observation of the location of the dimensional changes of the specimens was of interest. The linear dimensional changes at locations A-B and C-D may be considered a reflection of linear distortion, defined as the percent change dependent on the site of measurement. The linear dimensional changes at locations A-C and B-D may be considered a reflection of linear shrinkage, defined as the uniform dimensional change independent of the site of measurement. Thus, relative distortion of the anterior and posterior sections of the specimens may be judged by the dimensional changes occuring at locations A-B and C-D as noted by Woelfel et al (153). If the contraction or expansion over the two distances A-B and C-D was greatly out of proportion, Woelfel assumed that the warpage would be high (153). In the present study, the linear dimensional change between the posterior reference points C-D was more apparent than the other locations. This finding is in agreement with Stafford et al (135) and in conflict with that observed by Goodkind and Shulte (50).

In this investigation, statistical analysis showed that significant differences existed between many of the fabrication techniques studied at all locations at all of the time periods. In particular, the sprinkle-on autopolymerizing acrylic resin techniques displayed less linear dimensional change than the other fabrication techniques across the dimension C-D at the 24 hour, 72 hour, and two week time intervals. It was also noted

that the vacuum-adapted resin sheet and autopolymerizing acrylic resin dough application technique displayed more linear dimensional change than all of the other techniques across the dimension C-D at the 24 hour, 72 hour, and two week time intervals.

From the results of this study, it may be concluded that in order to minimize the linear dimensional change of a removable acrylic resin orthosis after construction on a die-stone cast, but prior to removal, an autopolymerizing acrylic resin sprinkle-on additive fabrication technique (either one-stage or three-stage) may be preferred over an auto-polymerizing acrylic resin dough application technique, a vacuum-adapted resin sheet and autopolymerizing acrylic resin dough application technique, or a heat-cured acrylic resin denture processing technique. Immediately after construction and removal from the cast, an autopolymerizing acrylic resin sprinkle-on fabrication technique (either one-stage or three-stage) may be preferred over the other fabrication techniques studied. Within 24 hours, 72 hours, and two weeks after construction and removal from the cast, an autopolymerizing acrylic resin sprinkle-on fabrication technique (one-stage) may be preferred over the other fabrication techniques, except for the autopolymerizing acrylic resin three-stage sprinkle-on additive technique (Note: no statistical difference in linear dimensional change was observed between the one-stage and three-stage techniques at any of the five time intervals at $p < .05$).

For the past 50 years, studies evaluating storage methods for denture base acrylic resins have concluded that storage methods significantly affect dimensional stability (92,100,130, 131,135,140,141,154). The storage methods investigated in the present study were a wet environment and a dry environment. Significant differences in the linear dimensional change of the specimens were noted between storage conditions at only one of the time intervals. Specimens stored in a wet environment demonstrated significantly less linear dimensional change after two weeks than specimens stored in a dry environment ($p < .05$). This finding supports the results of other investigations (92, 100,130,131,135,141,154), but is in conflict with those reported by Goodkind and Shulte (50).

After saturation in water for two weeks the anticipated expansion took place for specimens stored in a wet condition, and this was very apparent at the posterior location C-D. In the case of the specimens fabricated by the one-stage sprinkle-on technique, the water immersion was sufficient to cause an expansion greater than the initial contraction and a final slight expansion occurred (see Table 1 and Figure 1). This observation is in agreement with the findings reported by Craig (32) and Ogle (104). They noted that autopolymerizing acrylic resin expands +0.01% across the posterior flange to flange dimension of maxillary dentures upon immersion in water for 10 days (104) to several months (32).

On the basis of these observations, researchers have suggested that this net positive dimensional change may cause autopolymerizing acrylic resin appliances to be slightly oversized (32). However, in the present study, net positive dimensional changes were observed only for the one-stage sprinkle-on autopolymerizing acrylic resin specimens (Design A) and not for the autopolymerizing acrylic resin specimens fabricated by either the three-stage sprinkle-on technique (Design B) or the dough application technique (Design C). If a slight expansion at the posterior dimension of an orthosis is desired, the results of this study suggest that the one-stage sprinkle-on technique may be preferred over the three-stage sprinkle-on or the dough application techniques.

Numerous empirical design features and construction techniques have been proposed and developed to cope with the inherent problems of distortion of removable acrylic resin orthoses. It is suprising to find that an investigation of empirical claims as to the advantages of a given fabrication technique has not appeared in the literature as of today. The five fabrication techniques evaluated in the present study were chosen as representative of those introduced in the literature with an empirical claim of superior properties, improved accuracy of fit, and greater dimensional stability (1,12,45,58,59,69, 86,112).

The Design D specimens constructed in the present study were representative of orthoses in the literature describing a

vacuum-adapted resin sheet and autopolymerizing acrylic resin dough adapted to the resin sheet fabrication technique (12). The specimens constructed in this manner demonstrated significantly more linear dimensional change at all of the time periods than specimens fabricated using the three non-dough application techniques. In particular, Design D specimens demonstrated significantly more linear dimensional change than Design E specimens constructed by the heat-cured acrylic resin denture processing technique. Thus, Becker, Kaiser, and Lemm's claim of improved accuracy of fit and greater dimensional stability for their fabrication technique, when compared to the heat-cured denture processing technique (12), appears unfounded and clearly remains unsubstantiated.

It should also be noted that the vacuum-adapted resin sheet and acrylic resin dough application technique may have appeared clinically to be more accurate and precise in fit than the heat-cured processing technique due to the poor adaptation of the vacuum-adapted resin sheet to the stone cast. Lack of detail and initimate adaptation of the resin sheet to the stone cast may have allowed for much easier seating of the orthosis in the mouth, even if significant distortions had occurred as a result of the fabrication technique. On the other hand, the heat-cured processing technique, due to its intimate adaptation to the stone cast and natural teeth, could not have allowed for significant distortions without noticeable difficulty in seating the orthosis in the mouth.

The acrylic resin dough application technique (utilized in Design C and D) may by itself not be the cause for the greater linear dimensional change noted at various time intervals. The dimensional stability of Design C was comparable to Design B and E at the later time intervals, yet demonstrated greater dimensional change at the earlier time periods. The Design D fabrication technique incorporated a polymerization method that may have contributed to the greater linear dimensional change. Certainly, the literature presents conflicting results (106,132) as to whether autopolymerizing acrylic resin should be cured in water under air pressure. It should be noted that Design C specimens were allowed to cure in air on a benchtop. Further research is indicated to determine if polymerization methods significantly affect the dimensional stability of removable acrylic resin orthoses.

No statistically significant differences in linear dimensional change were noted between Design A and Design B acrylic resin specimens at any of the locations at any of the time intervals ($p < .05$). This finding suggests that the incorporation of three segmental stages in a sprinkle-on technique for autopolymerizing acrylic resin does not seem to offer any advantages in terms of minimizing linear dimensional change when compared to a one-stage sprinkle-on fabrication technique. Thus, any claim for improved accuracy of fit and greater dimensional stability for a segmental sprinkle-on fabrication technique (61), when compared to a single stage

fabrication technique, appears unfounded and remains unsubstantiated.

A possible explanation for Design A and Design B fabrication techniques displaying similar dimensional stability might be that premature removal of the acrylic resin specimens from their die-stone research casts was avoided. The three stage sprinkle-on technique (Design B) allowed 20 minutes for each segment to complete polymerization (a total of 60 minutes for complete polymerization of the entire orthosis). In like fashion, the single stage sprinkle-on technique (Design A) allowed 60 minutes for the entire segment to complete polymerization (some laboratory technicians may routinely allow only 20-30 minutes). As a result, this prolonged curing time may have minimized distortion or warpage, thus enhancing the dimensional stability of the acrylic resin research specimens fabricated by either the one-stage or three-stage segmental sprinkle-on techniques.

Because of the advantages claimed for the visible light-cured acrylic resin materials (104) and a "simplified technique for occlusal splint fabrication" (60) introduced recently in the literature, an evaluation of their effects on dimensional stability may be considered desirable in the future. As a follow on to the present study, a comparison of the dimensional stability of orthoses constructed by either a sprinkle-on autopolymerizing acrylic resin technique or a visible light-cured acrylic resin technique is indicated.

By using original and precise research methodology, it appears that cumulative linear dimensional change may be evaluated to determine the relative dimensional stability of acrylic resin orthotic specimens constructed by different fabrication techniques. Whether or not the small differences noted in dimensional change will have any clinical importance remains to be investigated.

The magnitude of the cumulative linear dimensional changes of the specimens in the present study varied widely, although not exceeding 0.5 millimeters. Clinical research is indicated to determine if changes of this amount significantly affect the fit of removable acrylic resin orthoses. Since adverse forces may be transmitted to teeth and supporting periodontal structures by orthoses, optimum design based on the best available research data may preserve the health of the teeth and periodontium.

The relationship between dimensional stability and fit produced by various construction methods and materials may seem evident, but is unsubstantiated. There should be little doubt that identification and evaluation of these fabrication techniques and materials through further research are vital to our understanding of the oral dynamics of these appliances.

VII. SUMMARY

Widely varying opinions exist among clinicians and researchers concerning the design and construction of interocclusal stabilization appliances (orthoses). Numerous fabrication techniques for orthoses have been introduced in the literature with empirical claims for improved accuracy of fit and greater dimensional stability.

The purpose of this study was to determine if fabrication techniques and storage methods affect the dimensional stability of removable acrylic resin orthoses. The primary objective of this investigation was to utilize five fabrication techniques and two storage methods (representative of those in the literature) to construct and store acrylic resin specimens, and to visualize and quantify their linear dimensional change at varying time intervals over a two week time period.

The following results and conclusions can be drawn from this investigation:

1. No significant difference in linear dimensional change was noted between the one-stage and the three-stage sprinkle-on fabrication techniques at any of the locations at any of the time periods ($p < .05$).
2. This result suggests that the incorporation of three segmental stages in a sprinkle-on technique for autopolymerizing acrylic resin does not seem to offer

any advantages in terms of minimizing linear distortion when compared to a one-stage sprinkle-on technique.

3. The one-stage sprinkle-on technique (Design A) demonstrated significantly less dimensional change than the dough application (Design C), the vacuum-adapted resin sheet and dough application (Design D), and the heat-cured denture processing (Design E) techniques at location C-D for all five time periods ($p < .05$), except for the heat-cured denture processing technique (Design E) at Time 1.
4. The heat-cured acrylic resin denture processing technique (Design E) demonstrated significantly less dimensional change than the vacuum-adapted resin sheet and dough application technique (Design D) at the posterior location C-D at all time periods ($p < .05$), except at Time 2.
5. All specimens stored in a wet environment demonstrated significantly less dimensional change two weeks after fabrication than specimens stored in a dry environment ($p < .05$).
6. These results suggest the laboratory utilization of an autopolymerizing acrylic resin sprinkle-on fabrication technique and a wet storage method to minimize distortion prior to the clinical use of a removable acrylic resin orthosis.

APPENDIX

RAW DATA FOR RESEARCH SPECIMENS

	CONDITION	LOCATION	DESIGN	TIME 1	TIME 2	TIME 3	TIME 4	TIME 5
1	WET	AB	A	.0290	-.0540	-.0200	.0090	.0380
2	WET	CD	A	.0140	-.0620	-.1090	-.0500	.0140
3	WET	AC	A	-.0150	-.0560	-.0490	-.0490	-.0460
4	WET	BD	A	-.0160	-.0460	-.0670	-.0650	-.0520
5	DRY	AB	A	.0250	-.0350	-.0230	-.0380	-.0280
6	DRY	CD	A	.0330	-.0380	-.0460	-.0520	-.0640
7	DRY	AC	A	-.0350	-.0600	-.0770	-.1030	-.1020
8	DRY	BD	A	-.0700	-.0770	-.1050	-.1040	-.1220
9	WET	AB	A	.0530	.0390	-.0180	.0010	.0390
10	WET	CD	A	-.0090	-.0570	0	.0350	.1030
11	WET	AC	A	-.0150	-.0440	-.0500	-.0480	-.0530
12	WET	BD	A	-.0420	-.0650	-.0770	-.0720	-.0680
13	DRY	AB	A	-.0170	-.0510	-.0740	-.0960	-.1200
14	DRY	CD	A	-.0050	-.0890	-.0820	-.0580	-.0070
15	DRY	AC	A	.0070	-.0290	-.0670	-.0600	-.0900
16	DRY	BD	A	-.0060	-.0460	-.0860	-.0900	-.1060
17	WET	AB	A	-.0270	-.0510	-.0020	.0470	.0740
18	WET	CD	A	-.0100	-.0260	.0860	.1280	.1560
19	WET	AC	A	-.0190	-.0310	-.0910	-.0360	-.0380
20	WET	BD	A	-.0430	-.0800	-.0660	-.0540	-.0550
21	DRY	AB	A	.0080	-.0510	-.0190	-.0480	-.0630
22	DRY	CD	A	-.0110	-.0770	-.0610	-.0900	-.1360
23	DRY	AC	A	-.0490	-.1000	-.1160	-.1220	-.1440
24	DRY	BD	A	-.0170	-.0620	-.0540	-.0720	-.0950
25	WET	AB	A	.0270	.0300	-.0350	-.0290	.0080
26	WET	CD	A	.0120	-.0790	-.0670	-.0560	.0290
27	WET	AC	A	-.0290	-.0490	-.0540	-.0450	-.0490
28	WET	BD	A	-.0650	-.0860	-.0740	-.0930	-.0820
29	DRY	AB	A	.0050	-.0600	-.0410	-.0480	-.0610
30	DRY	CD	A	-.0040	-.0310	.0040	.0130	.0230
31	DRY	AC	A	-.0650	-.0840	-.0800	-.0890	-.1200
32	DRY	BD	A	-.0250	-.0550	-.0680	-.0730	-.0980
33	WET	AB	A	.0070	-.0380	-.0190	.0010	.0570
34	WET	CD	A	-.0070	-.1040	-.0680	-.0090	.1800
35	WET	AC	A	-.0260	-.0580	-.0580	-.0520	-.0560
36	WET	BD	A	-.0220	-.0630	-.0610	-.0530	-.0600
37	DRY	AB	A	-.0110	-.0540	-.0450	-.0550	-.0770
38	DRY	CD	A	-.0210	-.0510	-.0120	.0090	.0310
39	DRY	AC	A	-.0050	-.0370	-.0510	-.0530	-.0800
40	DRY	BD	A	-.0290	-.0550	-.0740	-.0850	-.0890
41	WET	AB	B	-.0460	-.1040	-.1080	-.1130	-.0940
42	WET	CD	B	-.0280	-.1520	-.1750	-.2070	-.1350
43	WET	AC	B	-.0680	-.0870	-.0940	-.1010	-.0850
44	WET	BD	B	-.0170	-.0310	-.0370	-.0250	-.0350
45	DRY	AB	B	-.0290	-.0970	-.0950	-.1120	-.1330
46	DRY	CD	B	-.0030	-.1030	-.1020	-.1240	-.1400
47	DRY	AC	B	-.0440	-.0670	-.0930	-.1070	-.1210
48	DRY	BD	B	-.0270	-.0480	-.0660	-.0910	-.0980
49	WET	AB	B	-.0140	-.0980	-.1070	-.1220	-.0910
50	WET	CD	B	-.0330	-.1510	-.2010	-.1820	-.1180
51	WET	AC	B	-.0150	-.0490	-.0640	-.0590	-.0580
52	WET	BD	B	-.0420	-.0640	-.0830	-.0780	-.0660
53	DRY	AB	B	-.0290	-.0940	-.1030	-.1230	-.1550

	CONDITION	LOCATION	DESIGN	TIME 1	TIME 2	TIME 3	TIME 4	TIME 5
54	DRY	CD	B	-.0180	-.1120	-.1390	-.1630	-.1870
55	DRY	AC	B	-.0360	-.0660	-.0740	-.1000	-.1090
56	DRY	BD	B	-.0140	-.0520	-.0600	-.0790	-.0910
57	WET	AB	B	-.0010	-.0760	-.0650	-.0690	-.0420
58	WET	CD	B	-.0110	-.1400	-.1990	-.1790	-.0660
59	WET	AC	B	-.0090	-.0630	-.0710	-.0660	-.0730
60	WET	BD	B	-.0020	-.0380	-.0470	-.0450	-.0460
61	DRY	AB	B	.0250	-.0390	-.0500	-.0580	-.0690
62	DRY	CD	B	.0200	-.0370	-.0410	-.0300	-.0670
63	DRY	AC	B	-.0160	-.0530	-.0660	-.0730	-.0920
64	DRY	BD	B	.0040	-.0350	-.0530	-.0540	-.0810
65	WET	AB	B	.0090	-.0480	-.0420	-.0160	-.0120
66	WET	CD	B	0	-.0570	-.0620	-.0340	-.0560
67	WET	AC	B	-.0470	-.0760	-.0820	-.0880	-.0670
68	WET	BD	B	-.0030	-.0320	-.0420	-.0320	-.0300
69	DRY	AB	B	-.0190	-.0620	-.0960	-.1200	-.1450
70	DRY	CD	B	-.0050	-.0620	-.1080	-.1400	-.1590
71	DRY	AC	B	-.0150	-.0450	-.0730	-.0890	-.0940
72	DRY	BD	B	.0040	-.0280	-.0560	-.0720	-.0720
73	WET	AB	B	-.0260	-.0720	-.0670	-.0500	-.0220
74	WET	CD	B	-.0100	-.0770	-.0810	-.0880	.0070
75	WET	AC	B	-.0180	-.0480	-.0570	-.0550	-.0490
76	WET	BD	B	-.0010	-.0360	-.0480	-.0440	-.0320
77	DRY	AB	B	-.0140	-.0540	-.0890	-.1120	-.1310
78	DRY	CD	B	-.0040	-.0560	-.0970	-.1160	-.1490
79	DRY	AC	B	-.0140	-.0490	-.0760	-.0840	-.0930
80	DRY	BD	B	.0100	-.0280	-.0510	-.0650	-.0620
81	WET	AB	C	-.0680	-.1620	-.1620	-.1600	-.0920
82	WET	CD	C	-.0100	-.2060	-.2440	-.2600	-.0410
83	WET	AC	C	-.0780	-.0420	-.0350	-.0340	-.0220
84	WET	BD	C	-.0250	-.0500	-.0430	-.0490	-.0300
85	DRY	AB	C	-.0570	-.1800	-.1740	-.1850	-.1750
86	DRY	CD	C	-.0630	-.3230	-.3270	-.3220	-.2610
87	DRY	AC	C	-.1490	-.1670	-.1740	-.1870	-.1760
88	DRY	BD	C	-.0390	-.1610	-.1670	-.1870	-.1900
89	WET	AB	C	-.0200	-.1310	-.1620	-.1650	-.1130
90	WET	CD	C	.0170	-.1730	-.3790	-.4050	-.2700
91	WET	AC	C	-.0080	-.0350	-.0330	-.0360	-.0090
92	WET	BD	C	-.0980	-.1290	-.1330	-.1270	-.1010
93	DRY	AB	C	.0070	-.1190	-.1360	-.1480	-.1400
94	DRY	CD	C	-.0530	-.3250	-.3510	-.3660	-.3020
95	DRY	AC	C	-.1210	-.1360	-.1530	-.1580	-.1660
96	DRY	BD	C	-.0430	-.0980	-.0770	-.0980	-.1090
97	WET	AB	C	-.0260	-.1220	-.1330	-.1370	-.0730
98	WET	CD	C	-.0280	-.2510	-.3170	-.3190	-.1620
99	WET	AC	C	-.0310	-.0630	-.0660	-.0630	-.0500
100	WET	BD	C	-.0600	-.0920	-.0840	-.0820	-.0590
101	DRY	AB	C	-.0420	-.1050	-.0890	-.0790	-.0730
102	DRY	CD	C	-.0390	-.1330	-.0200	.0080	.0340
103	DRY	AC	C	-.1290	-.1360	-.1440	-.1390	-.1620
104	DRY	BD	C	-.0780	-.1510	-.1540	-.1610	-.1630
105	WET	AB	C	-.0590	-.1340	-.1740	-.1770	-.1290
106	WET	CD	C	-.0570	-.2550	-.3220	-.3530	-.1880

	CONDITION	LOCATION	DESIGN	TIME 1	TIME 2	TIME 3	TIME 4	TIME 5
107	WET	AC	C	-.1670	-.1660	-.1630	-.1500	-.1280
108	WET	BD	C	-.1190	-.1080	-.1080	-.1080	-.0840
109	DRY	AB	C	-.1850	-.2380	-.2340	-.2480	-.2280
110	DRY	CD	C	-.1180	-.2820	-.2820	-.2720	-.2220
111	DRY	AC	C	-.1480	-.1650	-.1830	-.1800	-.1730
112	DRY	BD	C	-.1250	-.1290	-.1360	-.1430	-.1460
113	WET	AB	C	-.1700	-.2540	-.2480	-.2500	-.2250
114	WET	CD	C	-.1190	-.3120	-.3550	-.3680	-.2500
115	WET	AC	C	-.1910	-.2080	-.2010	-.1900	-.1710
116	WET	BD	C	-.1280	-.1280	-.1210	-.1320	-.1040
117	DRY	AB	C	-.0170	-.0960	-.1210	-.1390	-.1500
118	DRY	CD	C	-.1450	-.3390	-.3670	-.3540	-.3230
119	DRY	AC	C	-.2170	-.2350	-.2410	-.2510	-.2630
120	DRY	BD	C	-.1960	-.1950	-.1940	-.2060	-.2010
121	WET	AB	D	-.1740	-.2200	-.2620	-.2670	-.2660
122	WET	CD	D	-.1030	-.2650	-.4080	-.4740	-.4640
123	WET	AC	D	-.1390	-.1300	-.1470	-.1370	-.1270
124	WET	BD	D	-.1150	-.1210	-.1160	-.1080	-.1190
125	DRY	AB	D	-.0780	-.1420	-.1420	-.1440	-.1530
126	DRY	CD	D	-.0570	-.1770	-.2020	-.2150	-.2100
127	DRY	AC	D	-.1060	-.1100	-.1090	-.1210	-.1440
128	DRY	BD	D	-.1420	-.1690	-.1630	-.1810	-.1770
129	WET	AB	D	-.1470	-.2250	-.2480	-.2510	-.1840
130	WET	CD	D	-.0790	-.2580	-.4030	-.4440	-.3270
131	WET	AC	D	-.1130	-.1470	-.1290	-.1330	-.1050
132	WET	BD	D	-.1110	-.1190	-.1230	-.1160	-.0900
133	DRY	AB	D	-.1710	-.2630	-.2830	-.3140	-.2980
134	DRY	CD	D	-.0740	-.3950	-.5490	-.6020	-.5940
135	DRY	AC	D	-.1330	-.1440	-.1440	-.1530	-.1370
136	DRY	BD	D	-.1380	-.1520	-.1530	-.1640	-.1440
137	WET	AB	D	-.1520	-.2450	-.2730	-.2670	-.2140
138	WET	CD	D	-.0850	-.3590	-.5290	-.5790	-.4420
139	WET	AC	D	-.1500	-.1630	-.1570	-.1810	-.1380
140	WET	BD	D	-.1360	-.1650	-.1460	-.1250	-.1120
141	DRY	AB	D	-.2030	-.2920	-.3370	-.3840	-.4120
142	DRY	CD	D	-.1170	-.3920	-.5500	-.6080	-.6550
143	DRY	AC	D	-.1620	-.1680	-.1720	-.1900	-.2010
144	DRY	BD	D	-.1300	-.2370	-.1340	-.1310	-.1520
145	WET	AB	D	-.1370	-.1410	-.1610	-.1420	-.1130
146	WET	CD	D	-.0450	-.1300	-.2020	-.2560	-.2180
147	WET	AC	D	-.1070	-.1150	-.1060	-.1050	-.0810
148	WET	BD	D	-.0670	-.0650	-.0640	-.0680	-.0480
149	DRY	AB	D	-.1140	-.1750	-.2260	-.2430	-.2600
150	DRY	CD	D	-.1290	-.3140	-.4970	-.5030	-.4910
151	DRY	AC	D	-.2310	-.2150	-.2140	-.2340	-.2400
152	DRY	BD	D	-.0890	-.0800	-.0940	-.0990	-.1180
153	WET	AB	D	-.1390	-.1570	-.1960	-.1990	-.1430
154	WET	CD	D	-.0640	-.1990	-.3460	-.3980	-.3100
155	WET	AC	D	-.0840	-.0780	-.0940	-.0810	-.0630
156	WET	BD	D	-.0980	-.0900	-.0790	-.0810	-.0670
157	DRY	AB	D	-.1610	-.1960	-.2420	-.2450	-.2680
158	DRY	CD	D	-.0860	-.2450	-.3340	-.3630	-.3890
159	DRY	AC	D	-.1690	-.1740	-.1930	-.1790	-.1970

	CONDITION	LOCATION	DESIGN	TIME 1	TIME 2	TIME 3	TIME 4	TIME 5
160	DRY	BD	D	-.0890	-.0960	-.1020	-.1050	-.1160
161	WET	AB	E	-.0880	-.1700	-.1740	-.1760	-.1620
162	WET	CD	E	.0220	-.1200	-.1210	-.1220	-.1020
163	WET	AC	E	-.0470	-.0480	-.0490	-.0540	-.0500
164	WET	BD	E	-.0150	-.0300	.0010	-.0330	-.0220
165	DRY	AB	E	-.0810	-.1610	-.1620	-.1680	-.2030
166	DRY	CD	E	-.0630	-.2770	-.2850	-.2820	-.3480
167	DRY	AC	E	-.0660	-.0620	-.0740	-.0900	-.1220
168	DRY	BD	E	-.0510	-.0670	-.0750	-.0850	-.1220
169	WET	AB	E	-.0240	-.1450	-.1370	-.1340	-.1170
170	WET	CD	E	-.0230	-.2540	-.2550	-.2420	-.1880
171	WET	AC	E	-.0110	-.0580	-.0530	-.0530	-.0520
172	WET	BD	E	-.0920	-.1280	-.1300	-.1380	-.1280
173	DRY	AB	E	.0070	-.0950	-.1120	-.1130	-.1720
174	DRY	CD	E	-.0200	-.2590	-.2760	-.2760	-.3380
175	DRY	AC	E	-.0750	-.0810	-.0900	-.1010	-.1320
176	DRY	BD	E	-.0570	-.0670	-.0760	-.0920	-.1170
177	WET	AB	E	-.0310	-.1090	-.1250	-.1150	-.0970
178	WET	CD	E	.0250	-.0870	-.1200	-.1120	-.0890
179	WET	AC	E	-.1470	-.1470	-.1650	-.1550	-.1500
180	WET	BD	E	-.0620	-.0760	-.0740	-.0770	-.0700
181	DRY	AB	E	.0200	-.0570	-.0590	-.0710	-.0860
182	DRY	CD	E	-.0090	-.1270	-.1190	-.1240	-.1120
183	DRY	AC	E	-.1230	-.1100	-.1200	-.1330	-.1600
184	DRY	BD	E	-.0510	-.0460	-.0660	-.0700	-.1060
185	WET	AB	E	-.0790	-.1590	-.1950	-.1980	-.1750
186	WET	CD	E	.0270	-.0950	-.1250	-.1260	-.0910
187	WET	AC	E	.0350	.0200	.0230	.0180	.0310
188	WET	BD	E	.0160	.0030	.0090	-.0030	.0050
189	DRY	AB	E	-.0720	-.1680	-.1770	-.1940	-.2100
190	DRY	CD	E	-.0690	-.2330	-.2320	-.2550	-.2840
191	DRY	AC	E	-.1620	-.1390	-.1450	-.1630	-.1920
192	DRY	BD	E	-.0630	-.0580	-.0650	-.0800	-.1000
193	WET	AB	E	-.1290	-.1980	-.1880	-.1910	-.1730
194	WET	CD	E	-.0470	-.1670	-.2080	-.2170	-.1680
195	WET	AC	E	-.1000	-.0820	-.0820	-.0930	-.0760
196	WET	BD	E	-.0760	-.0780	-.0770	-.0740	-.0740
197	DRY	AB	E	-.1780	-.2800	-.3010	-.2950	-.3080
198	DRY	CD	E	-.0260	-.2410	-.2340	-.2420	-.2630
199	DRY	AC	E	-.1110	-.1090	-.1080	-.1170	-.1490
200	DRY	BD	E	-.1540	-.1530	-.1620	-.1790	-.1980

	CONDITION	LOCATION	INIT MEASURE	ON CAST	0 HOURS	24 HOURS	72 HOURS	TWO WEEKS
1	WET	AB	36.438	36.467	36.384	36.418	36.447	36.476
2	WET	CD	50.107	50.121	50.045	49.998	50.057	50.121
3	WET	AC	27.047	27.032	26.991	26.998	26.998	27.001
4	WET	BD	26.838	26.822	26.792	26.771	26.773	26.786
5	DRY	AB	36.391	36.416	36.356	36.368	36.353	36.363
6	DRY	CD	50.109	50.142	50.071	50.063	50.057	50.045
7	DRY	AC	26.981	26.946	26.921	26.904	26.878	26.879
8	DRY	BD	26.901	26.831	26.824	26.796	26.797	26.779
9	WET	AB	36.361	36.414	36.400	36.343	36.362	36.400
10	WET	CD	50.082	50.073	50.025	50.082	50.117	50.085
11	WET	AC	26.822	26.807	26.778	26.772	26.774	26.779
12	WET	BD	26.930	26.888	26.865	26.853	26.858	26.862
13	DRY	AB	36.471	36.454	36.420	36.397	36.375	36.349
14	DRY	CD	50.128	50.123	50.039	50.046	50.070	50.121
15	DRY	AC	27.020	27.027	26.991	26.953	26.960	26.947
16	DRY	BD	26.962	26.956	26.916	26.876	26.872	26.856
17	WET	AB	36.472	36.445	36.421	36.470	36.519	36.546
18	WET	CD	49.992	49.982	49.966	50.078	50.120	50.148
19	WET	AC	26.953	26.934	26.922	26.862	26.917	26.915
20	WET	BD	26.893	26.850	26.813	26.827	26.839	26.838
21	DRY	AB	36.573	36.581	36.522	36.554	36.525	36.510
22	DRY	CD	50.191	50.180	50.114	50.130	50.101	50.055
23	DRY	AC	26.917	26.868	26.817	26.801	26.795	26.773
24	DRY	BD	26.733	26.716	26.671	26.679	26.661	26.638
25	WET	AB	36.295	36.322	36.325	36.260	36.266	36.303
26	WET	CD	50.001	50.013	49.922	49.934	49.945	50.030
27	WET	AC	26.994	26.965	26.945	26.940	26.949	26.945
28	WET	BD	26.839	26.773	26.752	26.764	26.745	26.787
29	DRY	AB	36.439	36.444	36.379	36.398	36.381	36.374
30	DRY	CD	50.018	50.014	49.987	50.022	50.031	50.041
31	DRY	AC	27.023	26.958	26.939	26.943	26.934	26.903
32	DRY	BD	26.946	26.921	26.891	26.878	26.873	26.848
33	WET	AB	36.452	36.459	36.414	36.433	36.453	36.504
34	WET	CD	50.007	50.000	49.903	49.939	49.998	50.089
35	WET	AC	26.964	26.938	26.906	26.906	26.912	26.908
36	WET	BD	26.993	26.971	26.930	26.932	26.940	26.933
37	DRY	AB	36.416	36.405	36.362	36.371	36.361	36.345
38	DRY	CD	50.102	50.081	50.051	50.090	50.111	50.133
39	DRY	AC	26.846	26.841	26.809	26.795	26.793	26.766
40	DRY	BD	26.799	26.770	26.744	26.725	26.714	26.711
41	WET	AB	36.303	36.257	36.199	36.195	36.190	36.209
42	WET	CD	49.882	49.854	49.730	49.707	49.675	49.747
43	WET	AC	26.808	26.740	26.7[illegible]	26.714	26.707	26.723
44	WET	BD	26.750	26.733	26.719	26.713	26.725	26.715
45	DRY	AB	36.463	36.434	36.366	36.368	36.351	36.330
46	DRY	CD	50.081	50.078	49.978	49.974	49.957	49.941
47	DRY	AC	27.137	27.093	27.070	27.044	27.030	27.016
48	DRY	BD	26.761	26.734	26.713	26.695	26.670	26.663
49	WET	AB	36.451	36.437	36.353	36.344	36.329	36.363
50	WET	CD	50.095	50.062	49.944	49.894	49.913	49.977
51	WET	AC	27.019	27.004	26.970	26.955	26.960	26.961
52	WET	BD	26.866	26.824	26.802	26.783	26.788	26.802
53	DRY	AB	36.435	36.406	36.341	36.332	36.327	36.280

	CONDITION	LOCATION	INIT MEASURE	ON CAST	0 HOURS	24 HOURS	72 HOURS	TWO WEEKS
54	DRY	CD	50.041	50.023	49.929	49.902	49.878	49.854
55	DRY	AC	27.034	26.998	26.968	26.960	26.934	26.925
56	DRY	BD	26.827	26.813	26.775	26.767	26.748	26.736
57	WET	AB	36.414	36.413	36.338	36.349	36.345	36.372
58	WET	CD	50.185	50.174	50.045	49.986	50.006	50.119
59	WET	AC	26.980	26.971	26.917	26.909	26.914	26.907
60	WET	BD	26.946	26.944	26.908	26.899	26.901	26.900
61	DRY	AB	36.362	36.387	36.323	36.312	36.304	36.293
62	DRY	CD	50.083	50.103	50.046	50.042	50.053	50.016
63	DRY	AC	27.023	27.007	26.970	26.957	26.950	26.931
64	DRY	BD	26.805	26.809	26.770	26.752	26.751	26.724
65	WET	AB	36.298	36.307	36.250	36.256	36.282	36.296
66	WET	CD	50.245	50.245	50.188	50.183	50.211	50.189
67	WET	AC	27.023	26.976	26.947	26.941	26.935	26.956
68	WET	BD	26.848	26.845	26.816	26.806	26.816	26.819
69	DRY	AB	36.466	36.447	36.404	36.370	36.346	36.321
70	DRY	CD	50.172	50.167	50.110	50.064	50.032	50.013
71	DRY	AC	27.011	26.996	26.966	26.938	26.922	26.917
72	DRY	BD	26.684	26.688	26.656	26.628	26.612	26.612
73	WET	AB	36.419	36.393	36.347	36.352	36.369	36.397
74	WET	CD	50.030	50.020	49.953	49.949	49.942	50.037
75	WET	AC	26.905	26.887	26.857	26.848	26.850	26.856
76	WET	BD	26.873	26.872	26.837	26.825	26.829	26.841
77	DRY	AB	36.382	36.368	36.328	36.293	36.270	36.251
78	DRY	CD	50.110	50.106	50.054	50.013	49.994	49.961
79	DRY	AC	26.901	26.887	26.852	26.825	26.817	26.808
80	DRY	BD	26.932	26.942	26.904	26.881	26.867	26.870
81	WET	AB	36.378	36.310	36.216	36.216	36.218	36.296
82	WET	CD	50.008	49.998	49.802	49.764	49.748	49.967
83	WET	AC	27.073	26.995	27.031	27.038	27.039	27.051
84	WET	BD	26.745	26.720	26.695	26.702	26.696	26.715
85	DRY	AB	36.583	36.526	36.403	36.409	36.398	36.408
86	DRY	CD	50.073	50.010	49.750	49.746	49.751	49.812
87	DRY	AC	27.046	26.897	26.879	26.872	26.859	26.870
88	DRY	BD	26.856	26.817	26.695	26.689	26.669	26.666
89	WET	AB	36.362	36.342	36.231	36.200	36.197	36.249
90	WET	CD	50.167	50.184	49.994	49.788	49.762	49.897
91	WET	AC	26.932	26.924	26.897	26.899	26.896	26.923
92	WET	BD	26.914	26.816	26.785	26.781	26.787	26.813
93	DRY	AB	36.331	36.338	36.212	36.195	36.183	36.191
94	DRY	CD	50.204	50.151	49.879	49.853	49.838	49.902
95	DRY	AC	27.075	26.954	26.939	26.922	26.917	26.909
96	DRY	BD	26.908	26.865	26.810	26.831	26.810	26.799
97	WET	AB	36.403	36.377	36.281	36.270	36.266	36.330
98	WET	CD	50.188	50.160	49.937	49.871	49.869	50.026
99	WET	AC	27.115	27.084	27.052	27.049	27.052	27.065
100	WET	BD	26.702	26.642	26.610	26.618	26.620	26.643
101	DRY	AB	36.290	36.248	36.185	36.201	36.211	36.217
102	DRY	CD	50.192	50.153	50.059	50.172	50.200	50.226
103	DRY	AC	27.046	26.917	26.910	26.902	26.907	26.894
104	DRY	BD	26.903	26.825	26.752	26.749	26.742	26.740
105	WET	AB	36.347	36.288	36.213	36.173	36.170	36.218
106	WET	CD	49.978	49.921	49.723	49.656	49.625	49.790

	CONDITION	LOCATION	INIT MEASURE	ON CAST	0 HOURS	24 HOURS	72 HOURS	TWO WEEKS
107	WET	AC	27.045	26.878	26.879	26.882	26.895	26.917
108	WET	BD	26.700	26.581	26.592	26.592	26.592	26.616
109	DRY	AB	36.576	36.391	36.338	36.342	36.328	36.348
110	DRY	CD	50.158	50.040	49.876	49.876	49.886	49.936
111	DRY	AC	27.032	26.884	26.867	26.849	26.852	26.859
112	DRY	BD	26.726	26.601	26.597	26.590	26.583	26.580
113	WET	AB	36.523	36.353	36.269	36.275	36.273	36.298
114	WET	CD	50.187	50.068	49.875	49.832	49.819	49.937
115	WET	AC	27.077	26.886	26.869	26.876	26.887	26.906
116	WET	BD	26.964	26.836	26.836	26.843	26.832	26.860
117	DRY	AB	36.302	36.285	36.206	36.181	36.163	36.152
118	DRY	CD	50.012	49.867	49.673	49.645	49.658	49.689
119	DRY	AC	26.968	26.751	26.733	26.727	26.717	26.705
120	DRY	BD	26.878	26.682	26.683	26.684	26.672	26.677
121	WET	AB	36.575	36.401	36.355	36.313	36.308	36.309
122	WET	CD	50.180	50.077	49.915	49.772	49.706	49.716
123	WET	AC	27.071	26.932	26.941	26.924	26.934	26.944
124	WET	BD	26.865	26.750	26.744	26.749	26.757	26.746
125	DRY	AB	36.428	36.350	36.286	36.286	36.284	36.275
126	DRY	CD	50.098	50.041	49.921	49.896	49.883	49.888
127	DRY	AC	27.087	26.981	26.977	26.978	26.966	26.943
128	DRY	BD	26.934	26.792	26.765	26.771	26.753	26.757
129	WET	AB	36.386	36.239	36.161	36.138	36.135	36.202
130	WET	CD	50.068	49.989	49.810	49.665	49.624	49.741
131	WET	AC	26.984	26.871	26.837	26.855	26.851	26.879
132	WET	BD	26.813	26.702	26.694	26.690	26.697	26.723
133	DRY	AB	36.457	36.286	36.194	36.174	36.143	36.159
134	DRY	CD	50.084	50.010	49.689	49.535	49.482	49.490
135	DRY	AC	27.148	27.015	27.004	27.004	26.995	27.011
136	DRY	BD	27.077	26.939	26.925	26.924	26.913	26.933
137	WET	AB	36.464	36.312	36.219	36.191	36.197	36.250
138	WET	CD	50.043	49.958	49.694	49.5[illegible]	49.464	49.601
139	WET	AC	27.190	27.040	27.027	27.033	27.009	27.052
140	WET	BD	26.831	26.695	26.666	26.685	26.706	26.713
141	DRY	AB	36.481	36.278	36.189	36.144	36.097	36.069
142	DRY	CD	50.181	50.064	49.789	49.631	49.573	49.526
143	DRY	AC	27.033	26.871	26.865	26.861	26.843	26.932
144	DRY	BD	26.808	26.678	26.571	26.674	26.677	26.656
145	WET	AB	36.464	36.327	36.323	36.303	36.322	36.351
146	WET	CD	49.955	49.910	49.825	49.753	49.699	49.737
147	WET	AC	27.043	26.936	26.928	26.937	26.938	26.962
148	WET	BD	26.797	26.730	26.732	26.733	26.729	26.749
149	DRY	AB	36.408	36.294	36.233	36.182	36.165	36.148
150	DRY	CD	50.005	49.876	49.691	49.508	49.502	49.514
151	DRY	AC	27.109	26.878	26.894	26.895	26.875	26.863
152	DRY	BD	26.747	26.658	26.667	26.653	26.648	26.629
153	WET	AB	36.444	36.305	36.287	36.248	36.245	36.301
154	WET	CD	50.059	49.995	49.960	49.713	49.661	49.749
155	WET	AC	27.140	27.056	27.042	27.046	27.059	27.077
156	WET	BD	26.793	26.695	26.703	26.714	26.712	26.726
157	DRY	AB	36.409	36.248	36.213	36.167	36.164	36.141
158	DRY	CD	50.053	49.967	49.808	49.719	49.690	49.665
159	DRY	AC	27.205	27.036	27.031	27.012	27.026	27.008

	CONDITION	LOCATION	INIT MEASURE	ON CAST	0 HOURS	24 HOURS	72 HOURS	TWO WEEKS
160	DRY	BD	26.908	26.819	26.812	26.806	26.803	26.792
161	WET	AB	36.336	36.248	36.166	36.162	36.160	36.174
162	WET	CD	50.174	50.196	50.054	50.053	50.052	50.072
163	WET	AC	26.932	26.885	26.884	26.883	26.878	26.882
164	WET	BD	26.895	26.880	26.865	26.896	26.862	26.873
165	DRY	AB	36.214	36.133	36.053	36.052	36.046	36.011
166	DRY	CD	50.030	49.967	49.753	49.745	49.748	49.682
167	DRY	AC	26.898	26.832	26.836	26.824	26.808	26.776
168	DRY	BD	26.761	26.710	26.694	26.686	26.676	26.639
169	WET	AB	36.347	36.323	36.202	36.210	36.213	36.230
170	WET	CD	50.123	50.100	49.869	49.868	49.881	49.935
171	WET	AC	27.074	27.063	27.016	27.021	27.021	27.022
172	WET	BD	26.850	26.758	26.722	26.720	26.712	26.722
173	DRY	AB	36.558	36.565	36.463	36.446	36.445	36.396
174	DRY	CD	50.086	50.066	49.827	49.810	49.810	49.748
175	DRY	AC	27.022	26.947	26.941	26.932	26.921	26.890
176	DRY	BD	26.600	26.543	26.533	26.524	26.508	26.483
177	WET	AB	36.384	36.353	36.275	36.259	36.269	36.287
178	WET	CD	49.887	49.912	49.800	49.767	49.775	49.798
179	WET	AC	26.969	26.822	26.822	26.804	26.814	26.819
180	WET	BD	26.762	26.700	26.686	26.688	26.685	26.692
181	DRY	AB	36.241	36.261	36.184	36.182	36.170	36.155
182	DRY	CD	50.009	50.000	49.882	49.890	49.885	49.897
183	DRY	AC	26.979	26.856	26.869	26.859	26.846	26.819
184	DRY	BD	26.837	26.786	26.791	26.771	26.767	26.731
185	WET	AB	36.265	36.186	36.106	36.070	36.067	36.090
186	WET	CD	50.014	50.041	49.919	49.889	49.888	49.923
187	WET	AC	27.020	27.055	27.040	27.043	27.038	27.051
188	WET	BD	26.747	26.763	26.750	26.756	26.744	26.752
189	DRY	AB	36.450	36.378	36.282	36.273	36.256	36.240
190	DRY	CD	50.086	50.017	49.853	49.854	49.831	49.802
191	DRY	AC	27.101	26.939	26.962	26.956	26.938	26.909
192	DRY	BD	26.739	26.676	26.681	26.674	26.653	26.639
193	WET	AB	36.478	36.349	36.280	36.290	36.287	36.305
194	WET	CD	50.173	50.126	50.006	49.965	49.956	50.005
195	WET	AC	26.997	26.897	26.915	26.915	26.904	26.921
196	WET	BD	26.765	26.689	26.687	26.688	26.691	26.691
197	DRY	AB	36.326	36.148	36.046	36.025	36.031	36.018
198	DRY	CD	50.055	50.029	49.814	49.821	49.813	49.792
199	DRY	AC	26.952	26.841	26.843	26.844	26.820	26.803
200	DRY	BD	26.866	26.712	26.713	26.704	26.687	26.668

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VITA

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In June, 1984, he entered the joint Prosthodontic Post-doctoral Program at the University of Texas Health Science Center at San Antonio and at Wilford Hall Medical Center, Lackland Air Force Base, Texas. In May, 1985, he was admitted as a candidate for the Master of Science degree at the Graduate School of Biomedical Sciences. In June, 1987, he received a Certificate in Prosthodontics from Wilford Hall Medical Center, Lackland Air Force Base, Texas. He has been assigned to an overseas tour of duty at Yokota Air Force Base, Tokyo, Japan and will begin clinical duties as Assistant Chief, Prosthodontic Department, Hospital Yokota AFB, in August, 1987.

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