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## Bond Strength and Accuracy of the Combined Agar-Alginate Impression System

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BOND STRENGTH AND ACCURACY OF  
THE COMBINED AGAR-ALGINATE  
IMPRESSION SYSTEM

by

Xavier Lepe, D.D.S.

Loyola University, 1987

A Thesis submitted to the Faculty of the Graduate School  
of Loyola University of Chicago in Partial Fulfillment  
of the Requirements for the Degree of  
Master of Science

March 1987

## CURRICULUM VITA

Xavier Lepe, son of Javier and Dolores Lepe was born June 19, 1956, in Chicago, Illinois.

His elementary education was obtained in St. Rene Catholic School in Chicago, Illinois. His secondary education was completed in 1973 at the Secundaria No 2 in Guadalajara, Jalisco, Mexico.

In September, 1973, Mr. Lepe entered the preparatory college, Preparatoria No 2 of the Universidad de Guadalajara, receiving a Bachelor of Science degree in July, 1976.

He began his dental studies at the Universidad de Guadalajara in September, 1976, and graduated in 1980 with the Degree of Doctor of Dental Surgery.

His graduate studies began in the Department of Oral Biology of Loyola University in August 1983. Specialty training was in the Department of Prosthodontics, where a Specialty Certificate was awarded in May, 1985.

## DEDICATION

To my wife Rosa Irene, Father Javier and Mother Dolores, for their encouragement and support.

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## CHAPTER I

### INTRODUCTION

Rigid impression materials previously used in dentistry were well suited for use in edentulous patients, but posed a problem in cases with severe undercuts and for the dentulous patient. Impression plaster had to be intentionally fractured, removed in pieces and reassembled. Impression compound distorts or flows upon removal over the height of contour of the teeth resulting in an inaccurate impression, and ZOE impression paste cannot be removed from undercuts.

To improve on these techniques, a more flexible material was needed that could be introduced in a viscous state into the mouth and that would be sufficiently elastic when withdrawn from an undercut area allowing for the material to spring back to its original shape without any permanent distortion.

Agar was the first elastic impression material to be used in dentistry and was introduced by A.W. Sears (1) in 1937 for the construction of inlays, crowns, and fixed partial dentures.

During World War II agar impression material became scarce because Japan was the prime source of this material. This accelerated research to find a suitable substitute. As a result, Schoonover and Dickerson (2) introduced alginate in 1943.

It was thought that alginate would replace agar because of a number of inherent superior qualities, one of which was the ease of manipulation. Early investigations by Skinner (20) and Hollenback (21) indicated that the accuracy of alginate was slightly superior to that of agar. However, Hosoda (22) reported that Schwindling found it was highly inconsistent. It is now well known that the dimensional stability and surface detail of agar surpasses that of alginate.

Since 1951, several efforts have been made to bond agar to alginate for a combined impression with the idea of utilizing the accuracy of agar with the ease of manipulation of the alginate material. Within the past several years, new products have been marketed incorporating this concept. Reversible syringeable agar specially formulated to bond to most alginates were developed along with alginate which was specially modified to bond to most agar hydrocolloids commonly used in the United States.

Several investigators have reported the dimensional



stability and accuracy of the combined technique to be clinically acceptable when the materials are handled properly but very little has been reported about the quality of the bond between these two materials.

The purpose of this study was; to determine if the properties of the alginate would affect the accuracy of the agar, and to determine if the bond between the two materials would be sufficient in order to obtain an accurate impression from which clinically acceptable prostheses could be constructed.

## CHAPTER II

### REVIEW OF THE LITERATURE

#### INTRODUCTION

Reversible hydrocolloid impression materials were introduced by Sears (1) in 1937 and have been the standard of accuracy in dentistry for over 40 years. Dentists world wide have discovered that for the most precise work these materials have proven themselves to be consistently accurate, and the standard against which other impression materials have been measured.

In 1943 Schoonover and Dickerson (2) introduced irreversible hydrocolloid (alginate) as a substitute for agar impression materials. Their general use far exceeds that of agar because: (1) It is easy to manipulate, (2) It is comfortable for the patient, and (3) It is inexpensive and does not require elaborate equipment. While having all these favorable properties, accuracy and surface detail of alginate is poorer than that of agar hydrocolloid.

## History

Many attempts have been made since 1951 to use agar and alginate in a combined technique. The idea was to eliminate that unfavorable characteristics of these materials while at the same time taking advantage of and combining the favorable characteristics of each material.

Investigations in 1956 of the combined technique found that the irreversible hydrocolloid did not bond with the reversible hydrocolloid and that any bond was strictly mechanical. Because of this, since 1980, several agars and alginates have been modified by the manufacturer to bond to each other.

Recent studies have shown that using these newer materials, clinically acceptable results can be achieved in terms of accuracy but very little study has been done on the quality of the bond.

## Material Science Aspects

Colloids due to their differences in structure, constitution and reactions are often classed as a fourth state of matter known as the colloidal state.

Colloids represent a particle distribution similar to the molecular distribution in a solution where there is

mutual attraction between the solute and the solvent molecules.

When the particles are large enough to be seen with the naked eye or through the microscope, the system is termed suspension; or emulsion, if liquids are distributed in liquids. Somewhere between the small molecules in solution and the very large particles in suspension is the colloidal dispersion.

True solutions exist as a single phase while both the colloid and the suspension have two phases, the dispersed phase or dispersed particle and the dispersion phase or medium.

In the colloidal state the particles in the dispersed phase may consist of molecules that are held together by primary or secondary forces. Often, the molecular attraction is the result of dipoles. Like any two phase system, particle size, surface energy, surface charge and wettability will determine the stability of the colloid.

Colloid sols may be composed of any combination of states of matter except two gases. Since the hydrocolloid impression materials are solids suspended in liquids, they are lyophilic sols. When agar is dispersed in water, the particles attract the water molecules and swell in size, thus forming a hydrocolloid.

If the concentration of the dispersed phase in the hydrocolloid is sufficiently great the sol may change to a gel when the temperature is decreased. This is referred to as the gelation temperature. The particles will agglomerate to form chains or fibrils which may intermesh to form a brush heap structure and the medium is held in the interstices between the fibrils by capillary attraction or adhesion. These fibrils are held together by secondary molecular forces. These fibrils can also be formed chemically as in alginate.

In the reversible hydrocolloid the change from sol to gel and vice versa is essentially a physical effect induced by temperature change. The gel does not return to the sol at the same temperature that it solidifies, it must be heated to a higher temperature known as the liquifaction temperature. This lag between the different temperatures is known as hysteresis.

Although the final structures of the two types of gels are similar, the gels formed chemically in alginate are primary bonded and, therefore, can only return to the sol by a reversal of chemical reaction.

### Gel Strength

The gel can support considerable stress,

particularly shear, provided it is applied rapidly. But if the stresses are sustained a flow results, possibly as a result of disturbing the network between the medium and the fibrillar structure.

The greater the density of the brush heap structure the greater the stiffness and strength of the gel.

The lower the temperature in the reversible gel, the stronger the gel will be due to the reduction of the kinetic energy of the fibrils and as a result a shorter interfibrillar distance and more cohesion.

The strength of the irreversible hydrocolloid is not affected by temperature but can be increased by the addition of fillers and chemical modifiers.

### Imbibition and Syneresis

The gel may lose water by evaporation from its surface or by the exuding of fluid by the process of syneresis. On the other hand if the gel is put in contact with water, absorption of water will occur by a process known as imbibition.

### Composition and Structure of Agar

Agar is an organic hydrophilic colloid

(polysaccharide) extracted from certain types of seaweed. It is a sulfuric ester of a linear polymer of galactose. Structural formula of agar is shown in Fig 1.

The concentration of agar in a commercial dental reversible hydrocolloid is only 13-17 %. The principal ingredient by weight is water being 80 to 85 %. Modifiers are present in minor amounts but exert a considerable influence on the properties of the material. Table 1.

Borax is added to increase the strength of the gel and also can increase the viscosity of the sol so that a filler is unnecessary. Sulfates are added as a gypsum hardener or accelerator to overcome the effect which borate has on the setting of stone, consequently resulting in a soft gypsum surface. Commercial agar products contain a certain amount of filler for the control of strength, viscosity and rigidity. Some fillers used are diatomaceous earth, clay, silica, wax, rubber and similar inert powders.

Ingredients, such as thymol and glycerine, may be added as a bactericide and plasticizer respectively. Pigments and flavors are also usually added.

### Composition and Structure of Alginate

The chief ingredient is generally conceded to be a

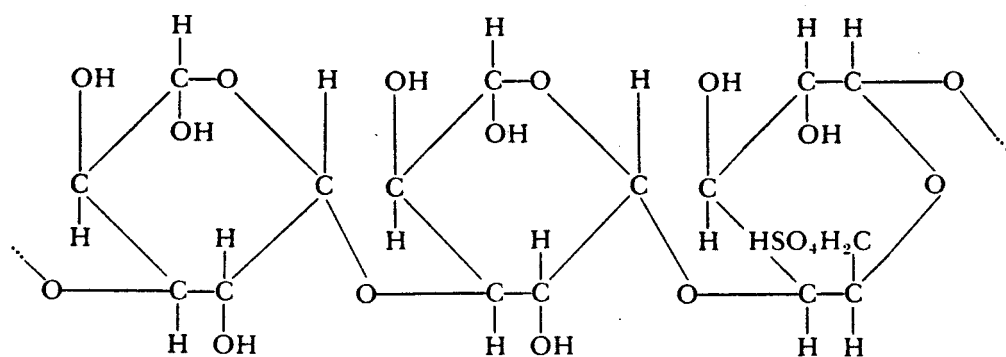


Fig. 1. Molecular structure of agar ( Phillips 1982 ).



Table 1

Composition of a Commercial Agar ( Phillips 1982 ).

Ingredient	Composition (Per cent)
Agar	13-17
Borates	0.2-0.5
Sulfates	1.0-2.0
Wax, hard	0.5-1.0
Thixotropic materials	0.3-0.5
Water	Balance

linear polymer of the sodium salt of anhydro-beta-d-mannuronic acid. Structural formula of alginate is shown in Fig. 2.

Alginic acid is insoluble in water but some of its salts are not. The acid can be changed to an ester salt very readily, since the polar carboxyl groups are free to react. Most of the inorganic salts are insoluble but the salts obtained with sodium, potassium and ammonium are dispersible in water. Sodium, potassium and triethanol amine alginate are used in dental impressions.

When mixed with water, dispersed alginates form a sol similar to the agar sol. The molecular weight of the alginate compounds may vary widely depending on the manufacturing treatment. The greater the molecular weight, the more viscous the sol.

There are a number of methods for the production of the chemical change that results in setting, the simplest is to react the dispersed alginate with calcium sulfate to produce insoluble calcium alginate as a gel. Calcium sulfate is used as a reactor while an added salt is used as a retarder like sodium or potassium phosphate, oxalate or carbonate in order for the reaction to take place in the mouth.

The composition of the alginate impression material

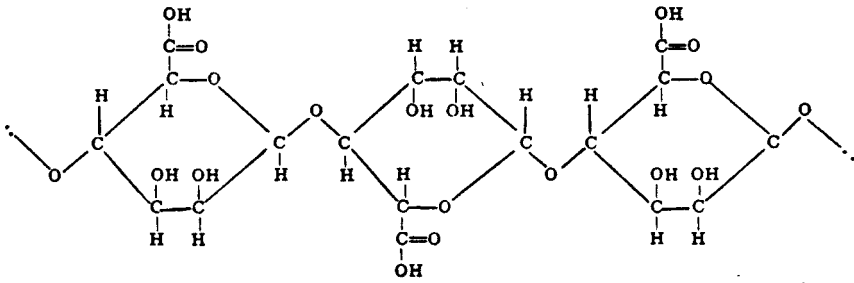


Fig. 2. Molecular structure of Alginic Acid from which Alginate is derived ( Phillips 1982 ).

is shown on Table 2.

Generally, the composition of a typical alginate impression material is an alginate, calcium sulfate as a reactor, sodium phosphate as a retarder, diatomaceous earth and zinc oxide as fillers and potassium titanium fluoride as a gypsum accelerator.

### Research

As mentioned previously Sears (1) in 1937 introduced reversible hydrocolloid as an impression material for the construction of inlays, crowns and fixed partial dentures. He mentioned that a great amount of time had been spent in order to simplify and clarify the procedure and that every step included had a definite bearing on the ultimate result. He divided the procedure in four parts: (1) carpule loading, (2) impression, (3) bite and (4) laboratory procedure. He also noted that there is no question of the accuracy of these materials for the use in inlays and fixed bridge construction.

In 1943 Schoonover and Dickson (2) introduced alginate as a substitute for agar. They compared this newer material with agar and found it to be comparable in strength, permanent set and ability to withstand strain under compression. Other advantages were: (1) low cost,

Table 2

Composition of an Alginate impression material (per cent by weight) Phillips 1982.

Potassium alginate	15%
Calcium sulfate	16%
Zinc oxide	4%
Potassium titanium fluoride	3%
Diatomaceous earth	60%
Sodium phosphate	2%

(2) adherence to smooth metal surface, (3) suitable for duplicating models, (4) ample working time, and (5) sufficient fluidity thus reducing the chance of trapping air.

In 1946 Skinner and Pomes (3) presented a logical technique for the manipulation of alginate and concluded that: (1) it should be poured immediately, (2) fixing solutions are necessary to overcome the effect of syneresis during setting of the stone, and (3) that when a good alginate was employed and manipulated properly the accuracy was equal to that of agar.

Schwartz (4) in 1951 described an alginate impression procedure for inlays using a celluloid syringe (Jiffy Tube) to place alginate in critical areas. He also was the first to suggest the combined alginate-agar technique.

Skinner and Hoblit (5) reviewed the combined alginate-agar technique in 1956 and emphasized that the two materials form a weak bond that is strictly mechanical and that a small perforated piece of metal should be inserted between the two hydrocolloids to physically enhance the bond. They determined that the dimensional stability of such an impression was clinically acceptable and equal to impressions of irreversible or reversible hydrocolloid impressions, if handled properly.

In 1980 Colloid 80 (formerly called Dentloid) was introduced. This is an injectable reversible hydrocolloid specially modified to bond to alginate. Appleby and others (6) studied Colloid 80 and two other conventional agars (Rubberloid and Surgident) in combination with three alginates (Jeltrate, S.S. White and Supergel) and found Colloid 80 to be the only agar to bond sufficiently to obtain adequate impressions. They found the three irreversible hydrocolloids to have different bond strengths with Colloid 80 and that combinations of Colloid 80 with Jeltrate or S.S. White exceeded clinical requirements. The combination of Colloid 80 and Supergel had the lowest bond strength and also had the lowest dimensional stability, but all three combinations with Colloid 80 were dimensionally clinically acceptable. In 1981 Appleby and others (7) discussed the clinical application of Colloid 80 and Jeltrate impression system for the construction of porcelain fused to metal restorations (PFM), removable partial dentures (RPD), partial veneer crowns and post & cores.

Fusayama and others (8) in 1982 introduced Dentroid bondable agar and Vericol Aroma, a new bondable alginate. The combination of these were shown by the authors to be dimensionally stable and gave the resultant die a surface accuracy equivalent to polysulfide or silicone rubber.

Appleby (9) in 1983 mentioned the use of the combined system and reported the technique to be comfortable for the patient, easy to do, fast and accurate.

Reed (12) in 1983 reported Colloid 80 and Jeltrate combination impression to be simple, accurate and inexpensive for MOD inlay restorations.

In 1984, Craig and Johnson (10-11) studied the accuracy and bond strength of four alginates in combination with three bondable agars and found alginates Coe and Jeltrate to be the most accurate in combination with the agars and considering both bond strength and accuracy, Coe alginate with Dentloid brown or green gave the best results.

In 1984 Herring and others (13-14) studied the dimensional stability of the combined impression Jeltrate-Colloid 80 with: alginate, agar, polysulfide, polyether, and vinyl polysiloxane and found no statistically significant difference between the various materials at the  $P < 0.05$  level.

Dahl and others (15) in 1985 studied the bonding properties and dimensional stability of the combination of Colloid 80 agar and Algiace alginate and compared it with three syringeable alginate systems and one conventional alginate. They claimed that all combinations can safely



be used to give clinically acceptable working casts if poured within 3 hours and 4 combinations if poured within 24 hours provided they are stored in 100% humidity. It seems unrealistic to obtain clinically acceptable casts from these materials after placing these impressions in a fixing solution for 20 minutes, much more unrealistic to pour them at 3 hours and inconceivable to pour them at 24 hours.

In 1985 Supowitz and others (16) reviewed two combination impressions, Jeltrate with Colloid 80 and with a new bondable agar, Cohere 602 for dimensional accuracy and surface detail. They compared these two combinations with polysulfide (Permalastic) and agar (Surgident) and found no significant difference in accuracy but found surface detail to be best with polysulfide, followed by agar. A syringeable alginate (JLB) and Ultrafine, an alginate substitute containing silicone were also reviewed for surface detail. Of all materials studied, these were found to be the poorest.

Appleby and others (17) in 1985 made a comparative analysis of the combined technique and used four bondable agars in combination with a conventional alginate (Jeltrate) and a bondable alginate (Alginate 80). They found no statistically significant difference in dimensional stability. The eight combinations

demonstrated sufficient accuracy for single-unit restorations but for multiple units they were questionable. The conventional alginate exhibited a stronger bond than the bondable alginate.

## CHAPTER III

### MATERIALS AND METHODS

A total of seven materials were used in this study, four bondable Agar hydrocolloids, two bondable alginates, and one conventional type alginate. All Agar hydrocolloids were of light body consistency, and all alginates were regular setting types. All materials were supplied by the manufacturer. The materials used in this study are shown in Table 3.

All materials were quantitatively proportioned; solids were weighed ( $\pm 0.1$  g) and liquids were measured in a graduated cylinder ( $\pm 0.5$  ml). Materials were mixed according to manufacturers instructions. The water volume for all alginates was increased by 10 %, which is recommended for this technique.

All Agar hydrocolloids were supplied as stick form, or pre-loaded carpules, except Cohere 602, which was supplied as a pre-loaded syringe. In order to evenly liquefy sufficient amounts of material it was necessary to cut several stick forms ,or material that was removed from the carpules into small pieces and place it in a 20 ml

TABLE 3

BRAND	MANUFACTURER	LOT #
<u>AGAR:</u>		
COHERE 602	GINGI-PAK	091285-1
COLLOID 80	U.S.SHIZAI	4120401
DENTLOID SUPER GREEN	DENTRONICS CO LTD	100601
SURGIDENT WITNESS	COLUMBUS DENTAL	111985 011486
<u>ALGINATE:</u>		
ALGINATE 80	U.S. SHIZAI	135-630
VERICOL AROMA	G-C DENTAL INDUSTRIAL CORP	210143
JELTRATE TYPE II	CAULK DENTSPLY	081285-9

syringe. Cohere 602 was liquefied in its own preloaded syringe. A Surgident Model 1 hydrocolloid conditioner (Los Angeles, Ca.) was used to liquefy the agar (Fig. 3).

Specimen preparation for tensile strength:

Tensile strength was determined by a method reported earlier by Sandrik (18). Specimens were fabricated by placing the aluminum die (Fig. 4) on a glass slab, filling the die with material, placing a second glass slab on top of the die, and holding the assembly together with two C-clamps to express excess material. Specimens were then placed in a 37 degree Centigrade waterbath (Fig. 5) for two minutes longer than the time recommended by the manufacturer for the material to remain in the mouth. Specimens were 3.8 cm long, 0.9 cm wide, and 0.6 cm thick (Fig. 6).

Tensile strength was determined on an Instron model 1130 universal testing machine (Instron Corp. Canton, Mass.) (Fig. 7) at a crosshead speed of 10 inches/ min using a 10 pound load cell. Data was read from a Houston super scribe recorder. Tests were performed immediately after the specimens were removed from the die. Eleven replicates were done for each material.



Fig. 3 Surgident Model 1 Hydrocolloid Conditioner.

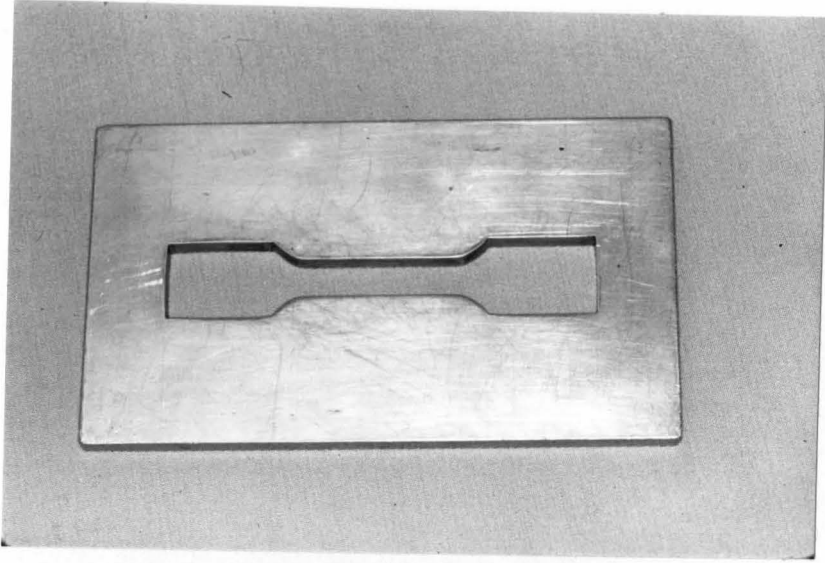


Fig. 4. Aluminum Tensile Strength Die.



Fig. 5. Magni Whirl constant temperature bath.



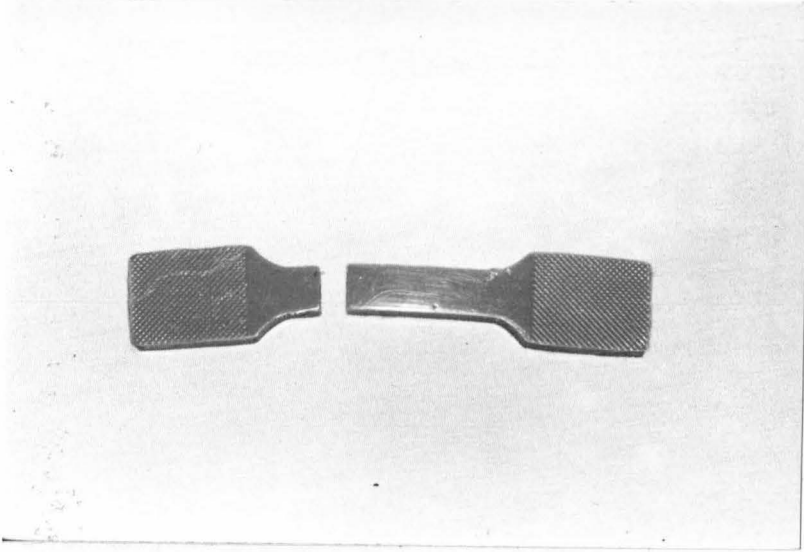


Fig. 6. Tensile Strength Specimen after testing.

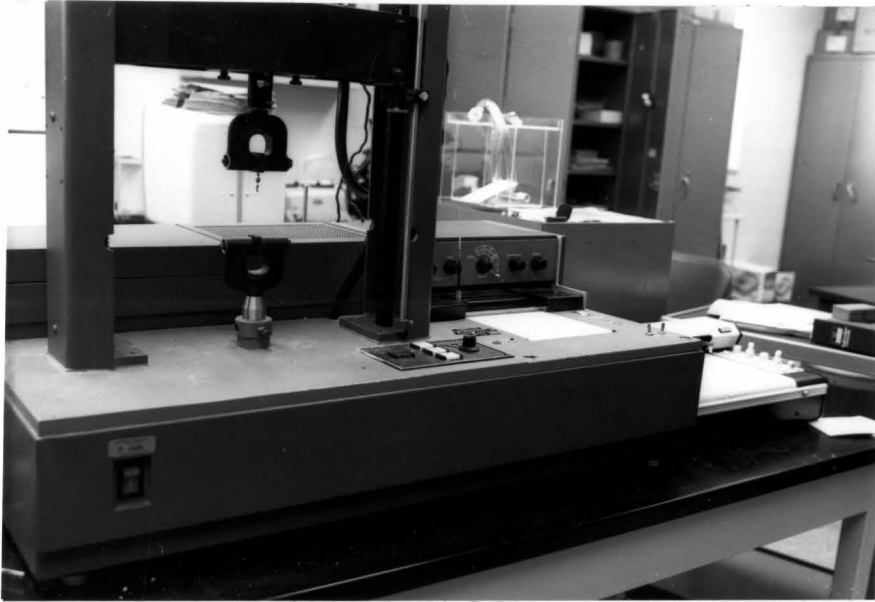


Fig. 7. Instron Model 1130 Universal Testing Machine.

## Specimen preparation for Tensile Bond Strength

Trial specimens were made similarly as for tensile strength except that a hard baseplate wax spacer was placed in the middle of the die, half of the die filled with alginate, the spacer removed, and then the other half of the die filled with Agar.

Two problems were encountered using this method:

1. An even interface between the two materials was very difficult to obtain.
2. The bonding surface area was too small making it difficult to obtain a reading on the Instron testing machine.

An alternative method was then used similar to one described by Craig (10) using a perforated mold (Fig. 8). A hydrocolloid liquid adhesive (Getz "New Hold") was painted on the Agar half of the mold and left to set ten minutes. Alginate was loaded in one half of the mold and Agar in the other. The excess leveled off and the two members aligned, and held in place for five minutes from the start of the mixing, without rotating either half. Then the assembly was placed in a 37 degree Centigrade water bath for two minutes longer than the recommended time for the alginate to remain in the mouth as specified by the manufacturer. The inside diameter of the mold was



Fig. 8. Tensile Bond Strength metal perforated mold.

0.3906 inches, which resulted in a bond area of 0.4793 square inches.

Tensile bond strength was measured on the Instron Testing machine at a cross head speed of five inches per minute using a ten pound load cell. Data was again read from a Houston Super scribe recorder. Tests were performed immediately after removing the specimens from the water bath and then five replicates for each of the twelve combinations were done.

### Accuracy

Trial specimens were made according to ANSI/ADA specification 19 using a type 316 stainless steel die (Fig. 9). This die presented a problem when making alginate specimens, because the specimens would stick to the highly polished surface even when using a separating medium (Super Surf).

There was also difficulty making combined agar/alginate specimens because the die had only one ring which acts as a container or tray for the impression material and there was no way of getting even layers of each material.

An acrylic die with the same characteristics as the other die was then fabricated (Fig. 10). This die had a

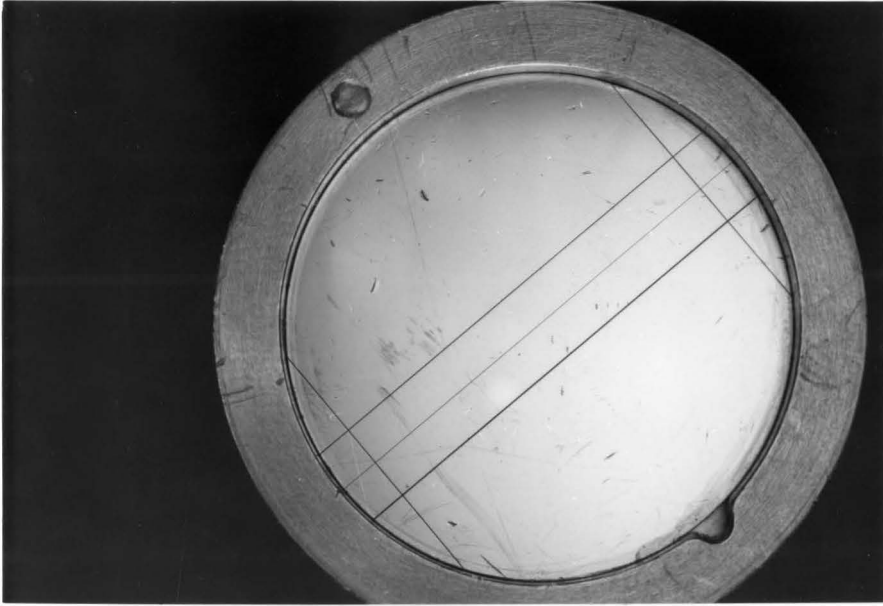


Fig. 9. Dimensional Accuracy stainless steel die.

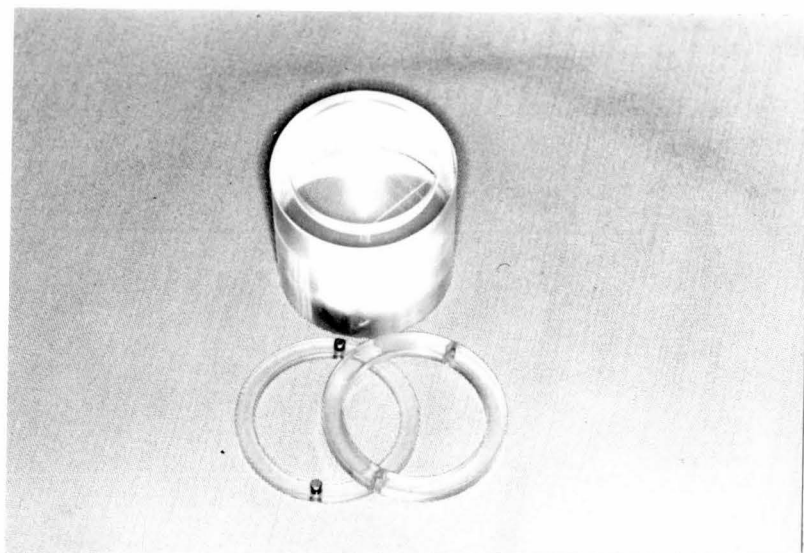


Fig. 10. Dimensional Accuracy acrylic die with two ring component for combined specimens.

one and a two ring component system which could be used for individual or combined material specimens. At the same time the difficulties associated with the alginate material sticking to its surfaces was not encountered.

A reference line on this acrylic die was replicated on the specimens for subsequent measurement of relative dimensional stability.

### Individual Material Specimens

The die was kept at room temperature, and the alginate was mixed and the agar was prepared according to manufacturers instructions. The materials were placed in the die and an acrylic plate was placed over the material. Again, excess material was extruded by pressing the acrylic down until it came to rest against the surface of the die. The acrylic plate and the die were held together using a C clamp. The assembly was then placed in a 37 degree Centigrade water bath for two minutes longer than the time recommended by the manufacturer for the material to remain in the mouth to ensure a complete set.



### Combined material specimens

Combined material specimens were tested in the same manner as for the individual materials. The only exception was that the two ring component on the die was used. One ring size was placed on the die and filled with agar and leveled off with a spatula tempered at 66 degrees C. The second ring was placed on the die and the alginate immediately was placed over the agar resulting in an agar thickness of 2mm and an alginate thickness of 2mm. The acrylic plate and C clamp were then used to hold the assembly together. The assembly was held in the water bath for two minutes longer than the recommended time to ensure intraoral set of the alginate material used for the combined specimen. This technique resulted in specimens with even layers of each material (Fig. 11).

The mean room conditions were 23 degrees Centigrade, and a relative humidity of 45%.

The samples were measured for dimensional stability with a Gaertner Traveling microscope (Fig. 12) graduated in 0.01 mm increments under a magnification of 32 x. Five specimens of each material and each material combination were evaluated. Immediately after the specimens were removed from the water bath, they were placed in a plastic

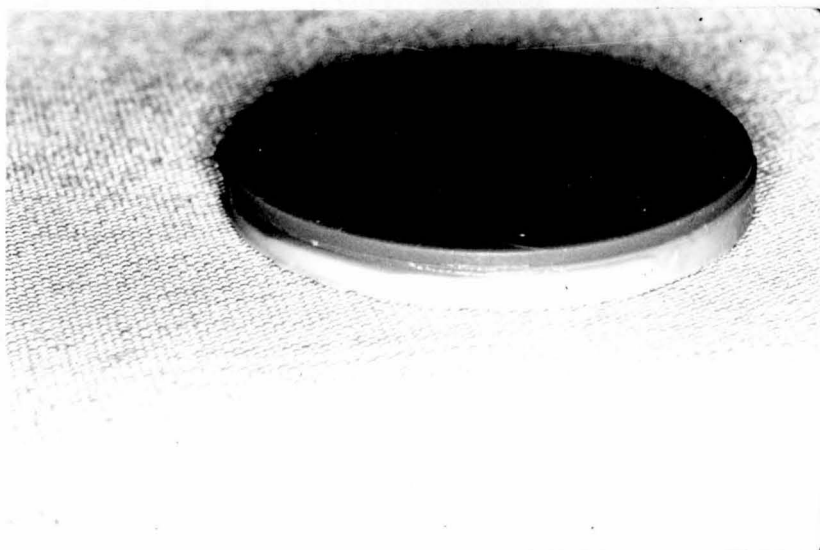


Fig. 11. Combined Agar-Alginate Dimensional Accuracy Specimen.

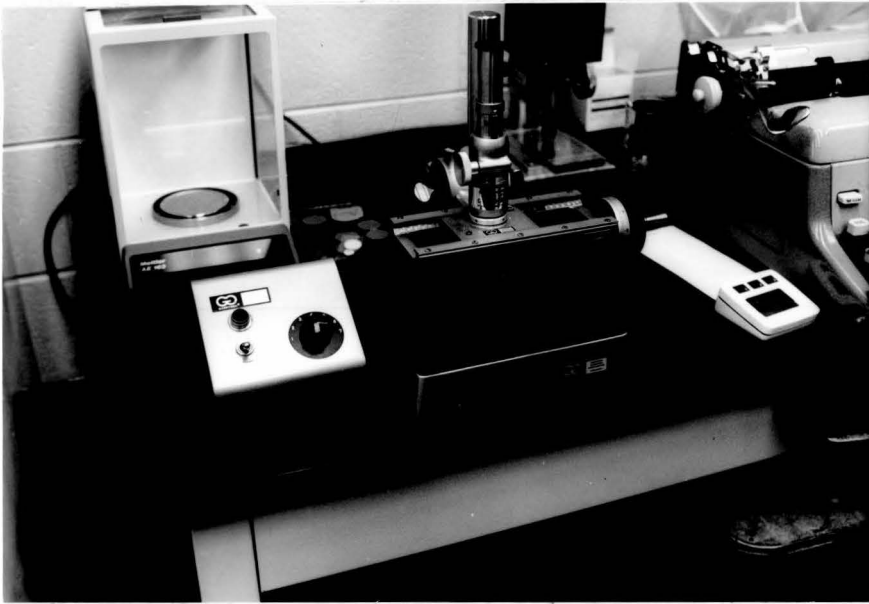


Fig. 12. Gaertner Traveling Microscope.

container lined with water saturated casting ring liner to maintain high humidity (Fig. 13). A slit was cut into the lid of the plastic container to facilitate viewing the specimen during measurement.

The length between the cross lines of the center line on the acrylic die was 24.993 mm (Fig. 14). The length of the center line as reproduced on each specimen was measured and recorded.

### Analysis of Data

Significant differences were tested by using Tukey's Studentized Range Test.

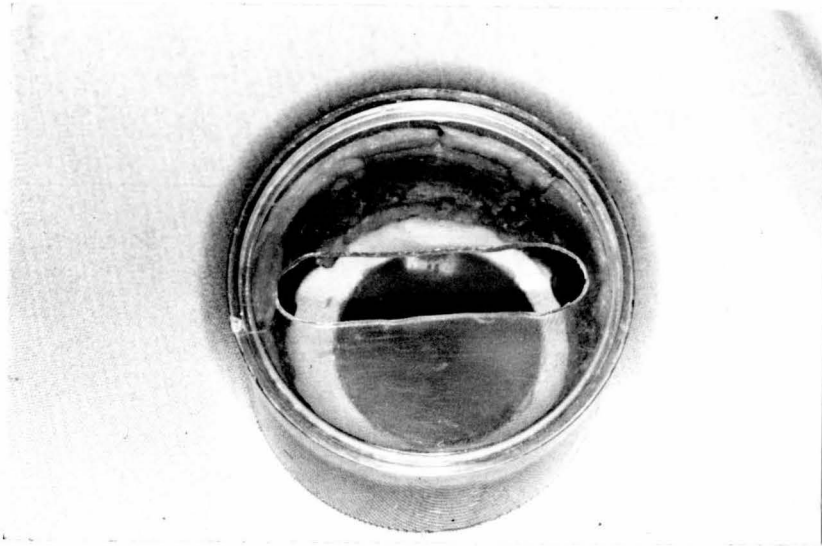


Fig. 13. Dimensional Accuracy Specimen in plastic container with a wet liner.

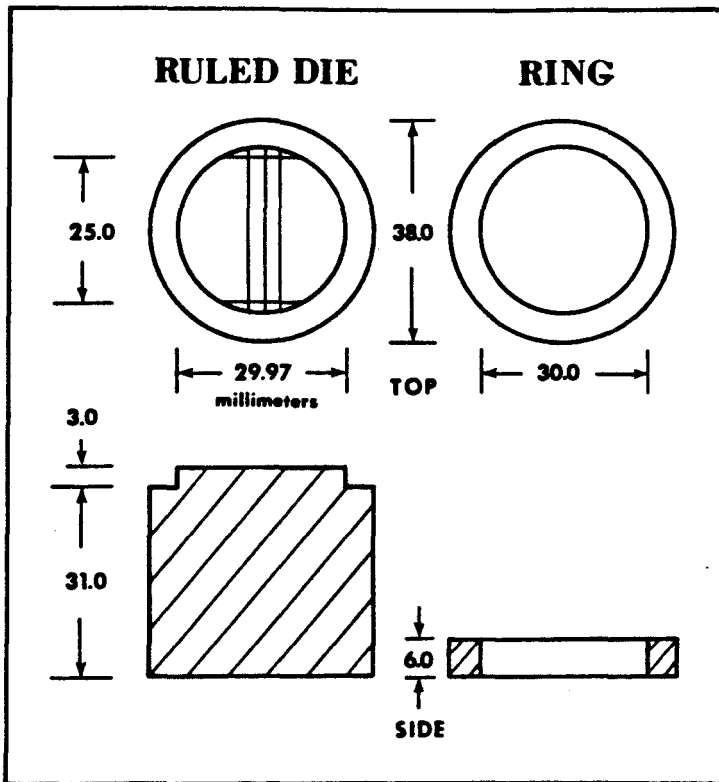


Fig. 14 Sketch of die used for Dimensional Accuracy ( Ciesco 1981 ).

## CHAPTER IV

### RESULTS

#### Tensile Strength

The mean values and standard deviations of the four brands of agars and three brands of alginates are shown on Table 4. Bar graphs for each material are shown on Fig. 15.

Tukey's Studentized Range Test for variables was performed on the results. At  $P=0.05$  level, it was found that Vericol Aroma alginate was significantly different than all other materials having the highest tensile strength. Alginate 80 and Jeltrate alginates had lower strength than Vericol Aroma but did not differ from each other.

Witness agar differed from the other three agars, having the higher tensile strength but was equal to Jeltrate alginate.

Dentloid and Cohere 602 did not differ from each other but did differ from Witness and Colloid 80 agars.

Colloid 80 differed from all of the other materials

Table 4

## TENSILE STRENGTH (PSI)

	$\bar{X}$	s.d.
MATERIAL	-----	-----
<b>AGAR:</b>		
Cohere 602	21.96	2.24
Colloid 80	13.51	1.54
Dentloid	23.34	2.70
Witness	30.40	2.14
<b>ALGINATE:</b>		
Alginate 80	34.17	1.41
Jeltrate	31.77	2.72
Vericol Aroma	38.73	1.60



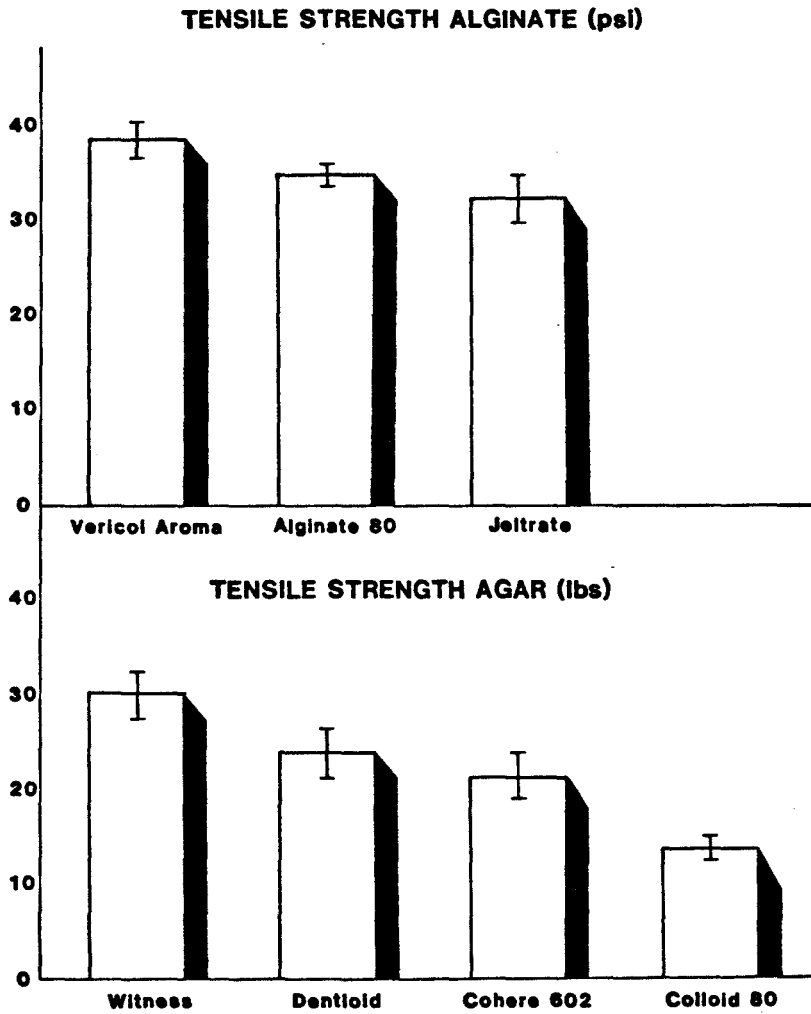


Fig. 15. Histogram showing Tensile Strength of Agar and Alginate.

studied and resulted in the lowest tensile strength.

### Bond Strength

The mean values and standard deviations of all combinations of materials is shown on Table 5. A Bar graph for each combination is shown on Fig. 16.

Tukey's Studentized Range Test for variables was performed on the results.

### Agars

Dentloid resulted with the highest bond strength and was significantly different than all other agars at the  $P=0.05$  level.

Colloid 80 and Witness differed from Dentloid but did not differ from each other

Cohere 602 differed from all others with the lowest bond strength.

### Alginates

No statistical significant difference was found between alginates.

### Combinations

No significant difference was found between any of the combinations of alginates with Cohere 602.

A significant difference was found between

Table 5

## BOND STRENGTH (PSI)

	$\bar{X}$	s.d.
MATERIALS	-----	-----
COHERE 602 WITH:		
ALGINATE 80	0.87	0.41
JELTRATE	0.80	0.10
VERICOL AROMA	1.16	0.13
COLLOID 80 WITH:		
ALGINATE 80	1.07	0.20
JELTRATE	2.72	0.44
VERICOL AROMA	1.64	0.33
DENTLOID WITH:		
ALGINATE 80	3.03	0.55
JELTRATE	2.09	0.65
VERICOL AROMA	2.36	0.35
WITNESS WITH:		
ALGINATE 80	2.61	0.45
JELTRATE	0.88	0.29
VERICOL AROMA	1.75	0.44

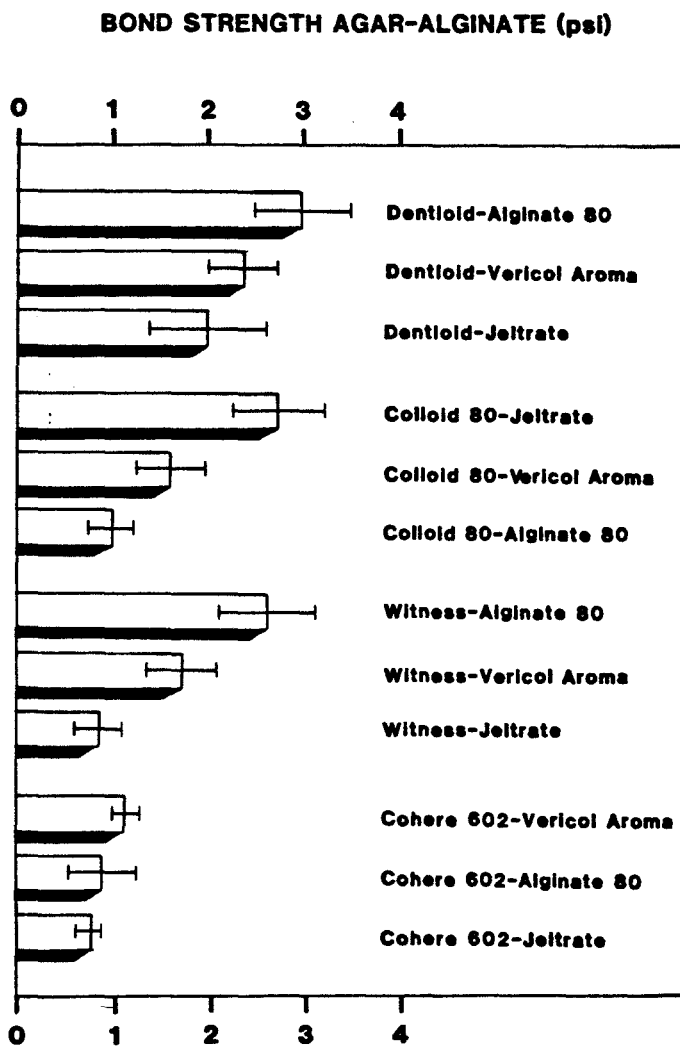


Fig. 16. Histogram showing Bond Strength of all Agar - Alginate Combinations.

combinations of Colloid 80. The combination with Jeltrate was better and differed from Vericol Aroma and Alginate 80 which did not differ from each other.

The combinations with Dentloid also differed from each other. Combinations with Alginate 80 differed from the combinations of Dentloid with Vericol Aroma and Jeltrate while these two were the same.

All combinations with Witness differed from each other, Alginate 80 being the best combination and Jeltrate being poorest.

Agars with Alginate 80 differed from each other. Dentloid and Witness did not differ from each other but were different from Colloid 80 and Cohere 602 which were not different from each other.

Combinations with Jeltrate also demonstrated significant differences. Colloid 80 and Dentloid were the same but differed from Witness and Cohere 602 which did not differ from each other.

In combination with Vericol Aroma, Dentloid and Witness did not differ from the other two agars, while Witness, Colloid 80 and Cohere 602 were the same.

### Dimensional Accuracy

The mean values and standard deviations of each

agar, alginate and combination of these are shown on Table 6. Bar graphs for each material are seen on Fig. 17 and for each combination on Fig. 18. Tukey's Studentized Range Test for variables was performed on the results.

### Agars

Witness was significantly different at the  $P=0.05$  level than the other three agars and was the most accurate agar by itself and in combination. Dentloid, Colloid 80 and Cohere 602 were not different from each other and followed Witness in the respective order.

### Alginates

Alginate 80 and Vericol Aroma did not differ from each other but differed from Jeltrate which was the only material (agar or alginate) to expand instead of shrink.

Alginate 80 and Vericol Aroma did not differ from Witness agar which was the agar with the best results by itself and in combination, so therefore these two alginates are different than any combination and any of the other three agars.

As mentioned previously, Jeltrate was different in that it expanded or stretched on removal from the die, so therefore it differed from all individual and combined materials.

## DIMENSIONAL ACCURACY ( % )

	$\bar{X}$	s.d.
MATERIALS	-----	-----
AGAR:		
Cohere 602	0.1496	0.1329
Colloid 80	0.1896	0.0823
Dentloid	0.1424	0.1207
Witness	0.0968	0.0535
ALGINATE:		
Alginate 80	0.0976	0.1036
Jeltrate	-0.3508	0.0987
Vericol Aroma	0.0808	0.0844
COHERE 602 with:		
Alginate 80	0.5289	0.0733
Jeltrate	0.4585	0.0548
Vericol Aroma	0.3016	0.0398
COLLOID 80 with:		
Alginate 80	0.3496	0.0664
Jeltrate	0.4185	0.0881
Vericol Aroma	0.3649	0.0611
DENTLOID with:		
Alginate 80	0.4265	0.0915
Jeltrate	0.2832	0.0770
Vericol Aroma	0.3821	0.1395
WITNESS with:		
Alginate 80	0.3320	0.0536
Jeltrate	0.2720	0.0926
Vericol Aroma	0.2648	0.0178

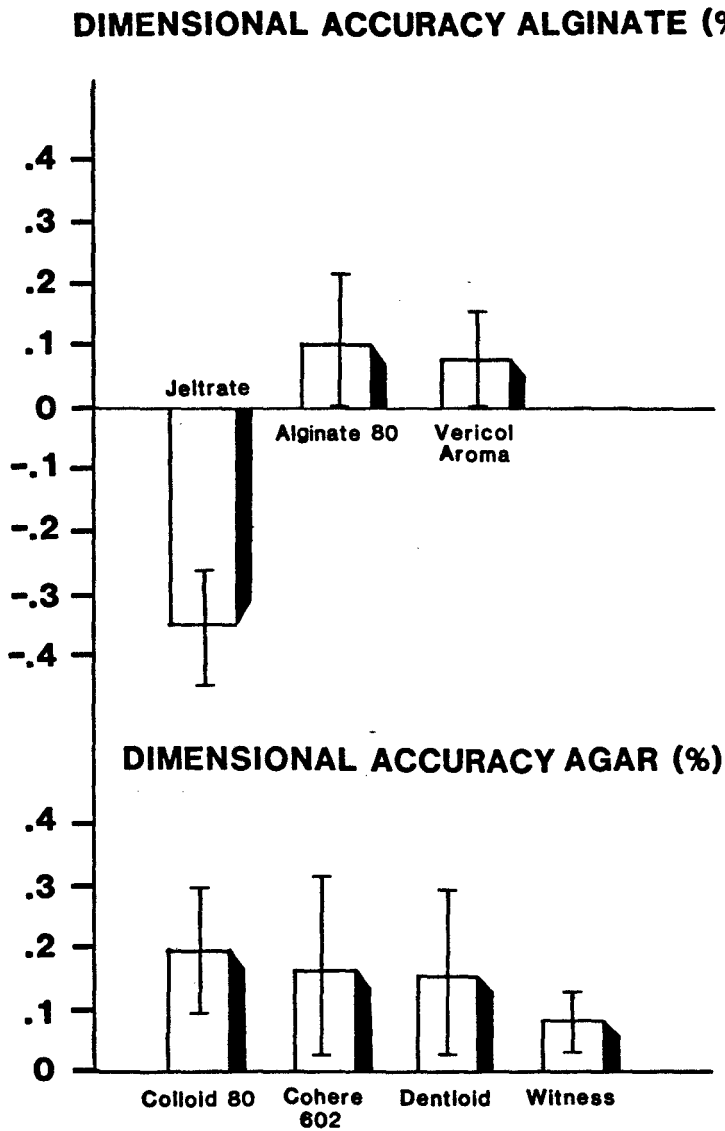


Fig. 17. Histogram showing Dimensional Accuracy of Agar and Alginate.



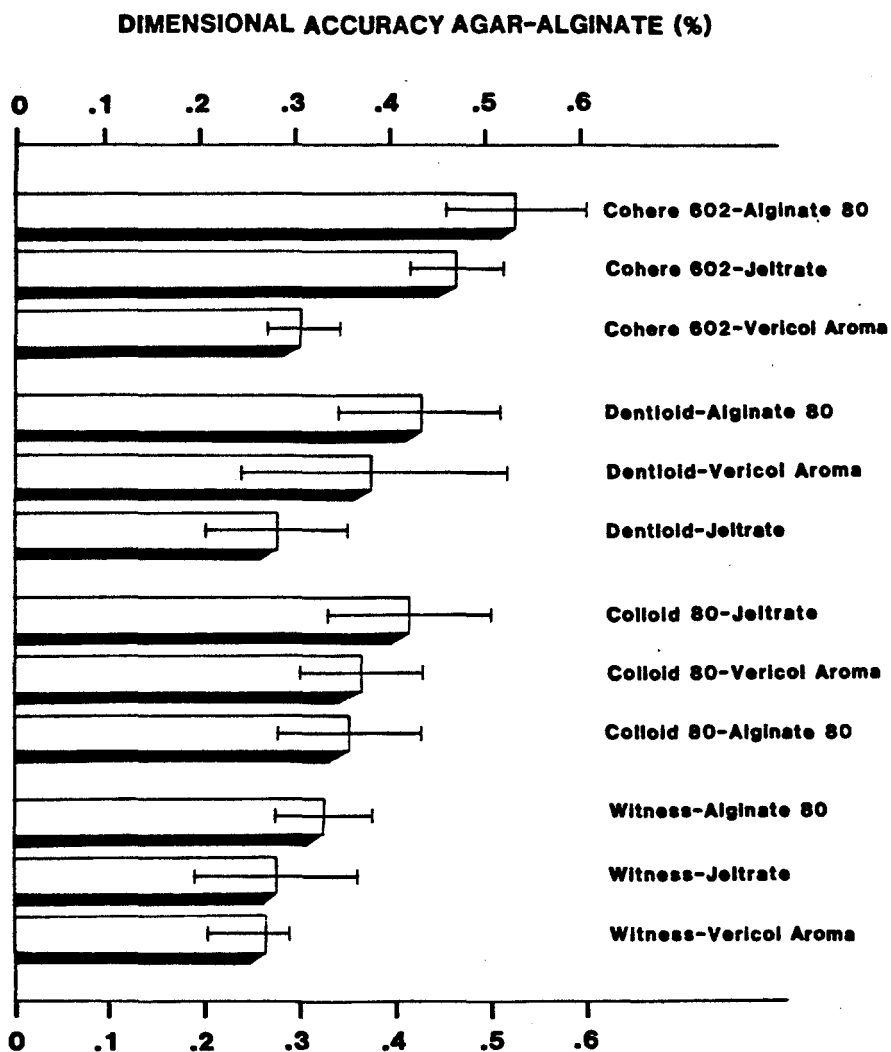


Fig. 18. Histogram showing Dimensional Accuracy of all Agar - Alginate Combinations.

### Combinations

All agars were more accurate individually than with any combination of itself with any of the three alginates and differed significantly from the combined specimens at the  $P=0.05$  level.

Combinations of Cohere 602 with Alginate 80 and Jeltrate differed from Vericol Aroma which was more accurate but they did not differ from each other.

All alginate combinations with Colloid 80 were not statistically different.

Dentloid combinations did differ from each other. Jeltrate combinations and Vericol Aroma combinations were the same. Vericol Aroma combinations and Alginate 80 combinations also did not differ, but there was a significant difference at the  $P=0.05$  level between Alginate 80 combinations and Jeltrate combinations, this being the most accurate.

No significant difference was found between alginate combinations and Witness.

## CHAPTER V

### DISCUSSION

Although agar is well known to produce accurate impressions in fixed prosthodontics, alginate on the other hand does not enjoy this reputation. One might assume that if agar is overlaid onto alginate, the unacceptable properties of the latter may dominate resulting in an unacceptable final result. The problem was to determine whether the acceptable properties of agar could be maintained in an impression consisting of agar bonded to alginate.

Several investigators have reported the dimensional accuracy of the combined agar-alginate impression to be clinically acceptable when the materials were properly handled but very little has been said about the quality of the bond between the two materials. It was important in this study to determine the bond strength between the different agars and alginates and to determine whether the bond had a direct effect on the dimensional accuracy of the combined impression system.

All of the previous studies had used one or more of

the newer modified bondable materials available for the technique but none had ever studied all of the bondable agars and alginates available at the present time. It was important in this investigation to study all the bondable materials manufactured specifically for the technique. Of special interest were those which had seldom been used in previous studies, for example Cohere 602 (agar), Alginate 80, and Witness which is the newest bondable agar to be introduced for this impression system.

Jeltrate alginate even though not designed as a bondable alginate was also included in this study because of the favorable results which were reported in several of the previous investigations.

Before testing the bond strength of the various combinations it was first necessary to determine the tensile strength of each individual material in order to relate this value to the adhesive bond between agar and alginate.

Tensile strength specimens were fabricated by a method earlier reported by Sandrik (18) because of the relative ease of preparation and testing procedures involved.

All materials for all specimens (tensile strength, bond strength and dimensional accuracy) were mixed or prepared according to manufactures' instruction with the

exception of the alginates where the water volume was increased by 10%, which is recommended for this technique.

All specimens were placed in a 37 degree C water bath for two minutes longer than that recommended by the manufacturer for the materials to set in the mouth, in order to ensure proper setting of the materials.

Tensile bond strength specimens were prepared using a method similar to that described by Craig (10) using a two piece perforated mold. A liquid adhesive was used on the agar half of the mold because the retention was not sufficient to maintain the material in place and false readings were being obtained at the time of testing on the Instron machine.

A track (Fig. 19) to align the two halves of the mold, similar to one used in previous studies, was discarded because it was impossible to get an even and complete interface of the entire diameter of the mold because of the fluid consistency of the materials at the time of alignment. For this reason the two halves of the mold were hand held in place in a vertical position with the precaution of not rotating either half and having the alginate half of the mold on the bottom because of its heavier consistency.

Dimensional accuracy specimens were fabricated on an acrylic die similar to that required for ANSI/ADA

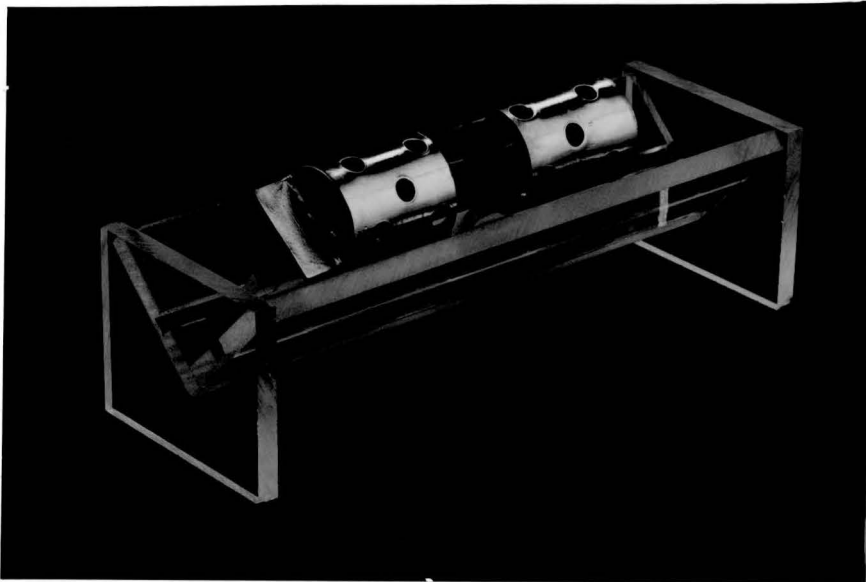


Fig. 19. Alignment device designed to secure the two halves of the tensile specimens. The device was later abandoned.

specification 19. This die provided a surface to which the materials did not stick, at the same time it has a one or two ring component system where individual specimens or even layers of combined material specimens could be obtained.

This method was preferred to the one mentioned in previous studies where an impression was taken of a master die with four abutments, the impression poured and measurements made on the stone cast. This method was chosen in order to follow ADA specifications in which the impression material is measured and not the cast obtained from the impression material. This eliminated dimensional changes occurring during the additional steps and also between the different materials used or interaction between these.

Of all the materials used, Colloid 80 had the poorest consistency and flow characteristics. The gel also seemed to lose more water from its surface by evaporation or syneresis and made it difficult to make measurements. It also appeared to contain more pigments than the other materials and would very easily stain anything in contact.

Tensile strength of alginates, as expected were higher than that of agars which may be attributed to the higher colloid concentration and amount of fillers.

Surprisingly, Witness agar was comparable to Jeltrate alginate which had the lowest tensile strength of the three alginates. Colloid 80 had the poorest tensile strength of all, possibly due to its poor liquification characteristics resulting in a less dense brush heap structure.

On the other hand, Colloid 80 performed well in tensile bond strength possibly because of its grainier consistency which provided a better mechanical lock. Dentloid resulted in the best bondable agar while Cohere 602 was the poorest.

Cohere 602 was the easiest agar to work with due to the fact that it was the only material available in a preloaded syringe.

Witness and Cohere 602 did not differ with any combination of alginates while Colloid 80 and Dentloid differed with each combination. This, in part, can be due to the inconsistency of the flow characteristics of Colloid 80 while Cohere 602 and Witness always had a good consistency.

In dimensional accuracy with agars and with combinations of agar-alginates Witness agar had the best results and was significantly different than the other agars.

It was interesting to find that all agars had better



accuracy by themselves than when combined with any alginate, which indicates that there is an interaction between the accuracy of alginate and the accuracy of the agar, and this conclusion can be made because the reproduction of the lines for measurement on the die was made on the agar half on the combined specimens.

Alginate 80 and Vericol Aroma were as accurate as Witness agar. It was not expected for these materials to compare with any agar, especially Witness which was the best agar in this study.

All Jeltrate specimens expanded. This was the only material to expand so the mixing and handling procedures were revised and five more specimens made. These came out with results identical to the first group. It is thought that Jeltrate's low tensile strength which may be caused by the extra 10% water volume may have caused this material to stretch on removal or expand after removal from the die.

It might be reasonable to question whether the superior dimensional accuracy of Alginate 80 or Vericol Aroma compared to Jeltrate, was due to less adhesion to the die and subsequently less stretching upon removal. Since the agar samples did not show any adhesion to the die, removal of these samples did not involve stretching. Were Alginate 80 and Vericol Aroma more accurate or did

slight adhesion to the die involve some stretching which appeared to overcome the natural shrinkage of these materials?

One thing which was not studied in this project but should be mentioned is that the surface detail observed in the microscope was far better in the agars than in the alginates.

## SUMMARY

Agar hydrocolloid has been successfully used as an impression material in Fixed Prosthodontics for over fifty years. Several efforts have been made since 1951 to unite it with alginate for a combined impression system. Recently, several manufacturers have modified both alginate and agar for this purpose. The dimensional accuracy of this combined system has been studied and compared to the most commonly used impression materials in restorative dentistry, but very little has been done with respect to the tensile bond strength between the two materials.

In this investigation, tensile strength, bond strength and dimensional accuracy of four brands of bondable agars, two bondable alginates and one conventional alginate were studied. Significant differences were found to exist between the individual materials and also the combined materials.

Knowledge obtained from this study demonstrated that even though the combined system may be clinically acceptable as reported in previous studies, any combination of materials was significantly less accurate

than any agar used by itself. Although the bond strength results of the different combinations were low, the mechanical interlocking of the materials during impression taking might be sufficient to be clinically acceptable. It is critical to choose a compatible combination of materials since certain combinations performed better than others. For example, Witness/Vericol Aroma was superior to Colloid 80/Alginate 80.

Further research is necessary to answer clinical questions created by this investigation. For example: although the data generated by this study, as well as that reported by others, indicated the combined agar-alginate technique produced acceptable results; will the technique be acceptable for multiple unit fixed prosthodontics?

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The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Science.

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