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THESIS

COMPARISON OF HEAT-CURE ACRYLIC RESIN PROCESSED BY MEANS OF THE CONVENTIONAL COMPRESSION MOULDING VERSUS THE DRY HEAT-HIGH PRESSURE PROCESSING TECHNIQUE

BY

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ABSTRACT

Since the introduction of acrylic resin in dentistry, there has been a continual search for modified practices in processing the resins which will lead to improved qualities.

The objective of this investigation was to determine the feasibility of processing acrylic resin with a dry heat-high pressure processing technique and ascertain its limitations by comparing samples of three different heat-cure acrylic brands made in 1, 2, 3 mm thickness with those processed by conventional compression molding techniques.

Since the ultimate success or failure of a prosthesis depends on its fit, which is the reflection of its dimensional stability, and since all acrylics have the property of water sorption, which compensates partially or completely for the curing shrinkage, this investigation was designed to study the water sorption, dehydration, and porosity. These factors are also essentially properties for retaining a clean, hygenic prosthesis.

The results of this study indicated that the short curing time afforded by the dry heat-high pressure processing technique is extremely useful, and the quality of the acrylic resin produced is comparable to that produced by the more common compression molding technique. This indicates that the dry heat-high pressure can be used to rapidly process acrylic resin for complete or removable partial dentures, denture bases, and for maxillo-facial prosthetic devices.

The dry heat-high pressure is a valuable asset to the prosthetic laboratory.

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INTRODUCTION

INTRODUCTION

Prior to the introduction of acrylic polymers to Dentistry in 1937, materials such as porcelain, nitrocellulose, phenol-phormaldehyde, and vinyl plastics had been used for denture bases.

The development of resin for a denture base material was an important advancement in prosthetic dentistry. In the United States of America, poly methyl methacrylate has dominated the field of denture base plastics since it was first introduced in the late 1930's. This long continued dominance is due to the fact that no other resin - and there have been hundreds of them - has been developed that has superior properties when used as a denture-base resin.

Physical changes in the acrylic denture base material and defects noticeable in the finished dentures seem to have centered more around the method and technique of mixing, packing, and processing the acrylic resin.

One of the undesirable properties of the acrylics is their contraction due to shrinkage which occurs during polymerization. Following initial shrinkage which takes place during polymerization, there follows another important property known as water sorption, the extent of which will ultimately affect the dimensional stability of the denture base and its serviceability.

There are available several methods of processing resins which eliminate the conventional water bath as a means of providing constant temperature. They are, the water vapor, the use of infra-red light as a source of heat with temperature control devices to regulate the processing, and the use of induction or dielectric heating of the resin mass to produce the molded finished product. Peyton, in 1950, found that air curing at equivalent temperatures to be equal to, but not superior to, water processing.

Veroninte, in 1946, employed the use of a dry air oven for processing the resin but it seemed to have the disadvantage in that precision temperature control was difficult as well as a slow heating rate to the interior of the flask. Preliminary work reported on this type of cure indicated that curing in an air oven at 160°F is equivalent, but not superior, to the process of curing in a water bath at the same temperature.

In the same year, 1946, Veroninte used dry heat developed by two electrically heated plates applied to the flask under compression, and concluded that this method worked satisfactorily but the control of heating required more elaborate equipment.

The objective of this study was to compare acrylic resin processed by dry heat-high pressure (The Desnoyer's Press) versus the conventional water bath processing technique with respect to:

1. Water sorption
2. Dehydration
3. Porosity

REVIEW OF LITERATURE

Contrary to generally accepted belief, acrylic resin (methyl methacrylate) is not new. Even before 1900, it was known, studied, and used. At that time, however, granular polymerization was unknown and the material required grinding and pulverizing before it could be used (Lowery, 1945). When acrylic resin (methyl methacrylate) was introduced as a denture material in 1937, it became immediately the most widely accepted material and still is (Sweeney, 1958).

Pickett and Appleby, in 1970, stated that acrylic monomer shrinks 21% during polymerizations. There is no volumetric change of the powder, since the monomer contributes 25% of the volume and the resultant volumetric contraction is about 5%. Only the linear change is a significant factor in determining the final adaptation of the processed denture.

Although there is some disagreement among authors regarding the amount of polymerization shrinkage of denture bases, at least one fact is concrete, namely, that the shrinkage which has been found after curing, is much lower in the actual denture than should be expected from the theoretical considerations.

Vieira, in 1961, reported some of the values for dimensional changes as found by various investigators.

Volumetric shrinkage
Carter: 1.75 - 3.25%
Dahl: 2 - 4%
Schroeder and Santoril: 7%

Linear shrinkage
Sweeney: 0.44 - 0.62%
Sweeney: 0.25 - 0.44%
Peyton and Mann: 0.35%
Jones and Skinner: 0.33%
Dahl: 0.6 - 1.33%

These observed differences may be due to several factors or to different conditions of research, but are mainly attributed to the inherent conditions of denture polymerization.

Hargreaves, in 1978, stated that in any consideration of the dimensional stability of an intraoral restorative material, the uptake of fluid has long been recognized as a major factor.

Phillips, in 1973, stated that (poly)methyl methacrylate absorbs water slowly over a period of time. The absorption is undoubtedly due primarily to the polar properties of the resin molecules. The diffusion presumably occurs between the macromolecules which are forced slightly apart, and is not unlike a plasticizer. Because the macromolecules are forced apart by the diffusion of the water, they are rendered more mobile with the result that inherent stresses can be relieved with a consequent relaxation and possible change in the shape of the denture.

Sweeney, in 1942, found that the expansion of (poly)methyl methacrylate resin during storage in water more than compensates for curing shrinkage resulting in an oversized denture.

Skinner and Cooper, in 1943, said that the inhibition of water by the resin generally compensates for the shrinkage that occurs during processing.

Sweeney, in 1958, stated that denture bases made of acrylic resin expand when placed in water or in the oral cavity until equilibrium is reached. This is at 1.5 to 2.0 percent sorption by weight. This amount of water will cause an expansion of about 0.3% linearly and compensates for about one-half of the curing shrinkage.

Miraza, in 1961, in measuring clinical dentures, observed that the greatest dimensional change is during the first month. During the second and third months, some expansion occurred and there was a leveling off at the end of this period.

Conversely, Woelfel, et-al, in 1959, said that linear changes which occur during processing are greater than subsequent changes.

Veroninte, in 1947, found that partial compensation is obtained by the fact that acrylic resin expands on the sorption of water at the rate of 0.23% linearly for 1% increase in weight of water absorbed.

Bates and Smith, in 1965, suggested that an uptake of approximately 2% w/w increase be regarded as the maximum for the uptake of water. This limit implies that there would be no serious reduction in the strength of the material in service, that its hygiene would be maintained, and that its associated expansion would not overcompensate to any great extent for processing contractions that had occurred or lead to the breakdown of an intimate bond with any other material.

In 1954, Brauer and Sweeney studied the effect of temperature and molecular weight on the water sorption of methyl methacrylate and concluded that at room temperature variations in water sorption of commercial materials are due to the presence of plasticizers and copolymers. Water sorption varies little in the 0^o to 60^oC range. Above the second order transition temperature, Tg, sorption increased markedly. No sorption equilibirum was reached on storage of specimens in boiling water for 200 days. At room temperature, specimens of different molecular weight showed small variation in water sorption. On storage in water above Tg, an increase in molecular weight produced a decrease in the amount of water sorbed. The increase in water sorption at elevated temperatures was due to the less rigid linkage between polymer chains and an expansion of the network structure which allowed water to permeate more readily into the material. The large increase in sorption above Tg must be considered in processing acrylic materials at elevated temperatures.

In 1958, Sweeney concluded that the variations in research reports on the exact dimensional changes in clinical cases due to water sorption are largely explained by the amount of water in the resin when the cure is finished.

Braden, in 1964, stated that the absorption of water by denture base polymers is of considerable importance since it is accompanied by dimensional changes. The rate at which water is absorbed and hence the time to equilibriate, is governed by a physical parameter known as the diffusion coefficient.

In 1964, Braden reported that for denture base resins, a maximum uptake of water after 24 hours for a given size of speciment had become the basis of the American, British, and International Standard's specifications. More recently, however, work has shown that this may be little more than a reflection of the diffusion coefficient for sorption rather than an indication of the total uptake.

The diffusion coefficient of a typical heat-cured denture acrylic resin is 1.08×10^{-8} per square centimeter per second at $37.4^{o}C$ ($99.3^{o}F$). This value is twice that of $22.5^{o}C$ ($72.5^{o}F$).

Barrer and Barrie, in 1958, reported that the diffusion coefficient is higher during desorption. Classic diffusion theory predicts equal values for the two processes. The disparity is due to a phenomenon common to many polymers, namely, the dependence of the diffusion coefficient on concentration. In fact, the diffusion coefficient D decrease with increasing concentration since D is highest during sorption (Crank, 1957).

In 1973, Phillips stated that when the acrylic resin is allowed to dry or desorb, the entire process is reversed quantitatively, provided the resin is stress free.

The data and conclusions from a series of five papers on the various aspects of dimensional changes in dentrues were published by the Dental Research Section of the National Bureau of Standards. Woelfel and Paffenbarger, 1959 - Woelfel, Paffenbarger, and Sweeney, 1960, 1961, 1962 and summarized by Paffenbarger, et-al, in 1954. Three general conclusions were made:

1. The thick dentures had less shrinkage on processing and less dimensional change during use, when wetter, dried in air, and heated in water, than the thin denture. Therefore, the denture should be made as thick as comfort and function will permit.
2. None of the dimensional changes that occurred during processing or in use could be detected clinically.
3. The conventional acrylic resins processed with the usual dental technique of compression moulding produced dentures that were just as stable as those produced by special resins and appliances.

Skinner, in 1951, found that the dimensional stability of dentures processed on metal casts is not the same as that of dentures processed on stone casts. The changes during immersion in water are greater for bases processed on metal casts.

The relationship of water sorption and retention of dentures was studied by Campbell in 1956. Nine dentures were studied in the laboratory; an elastomer resin was used to represent the soft tissues. Two dentures were tested clinically. The results of his investigation were that water sorption reflects increased retention and this continued for 85 days.

Schoonover, in 1952, suggested that since the occlusion of a denture is affected by the expansion or contraction of the resing resulting from a gain or loss of water, it is essential that final occlusal adjustments be made only after the denture has been exposed to moisture conditions similar to those encountered in actual service.

In 1969, Bevan and Earnshaw, studied the role of water sorption in the solvent crazing of acrylic resins and warned of the danger of solvent crazing when repairing or realigning a denture that has been in service. They suggested a way to minimize it which is to ensure that the resin is saturated before exposing it to monomer. If the denture has partly dried, craze resistance may be restored by immersing it in room temperature water for at least 12 hours and preventing any surface drying before packing or pouring the repair material. It was found that saturated specimens were resistant to solvent crazing, as were those that had lost at least 65% of their saturation water content. Specimens were most susceptible to solvent crazing in the early stages of drying, because of the existence of surfac tensile stresses set up by differential contraction of the resin.

As far back as 1943, the problem, cause and cure of porosity has been studied. These studies suggested that the porosity was a frequent draw back in acrylic resin and, with due care and understanding, it could be avoided and eliminated (Mewar, 1955).

Phillips, in 1973, stated that there are a number of causes of porosity which may occur during the processing of the denture base. If the porosity appears on the surface of the denture, proper cleaning will be unsightly. Even though the porosity may be entirely internal, the denture base will be weakened. Furthermore, since each internal pore or pleb is an area of stress concentration, the denture may warp as the stresses relax.

There are currently several proposed theories concerning the cause of internal porosity in denture resins. Tuckfield, in 1943, suggested that the vapor of the boiling monomer trapped in the rapidly polymerization resin leaves voids. The development of such porosity is caused by the boiling of the monomer when the curing temperature reaches the boiling stages.

The boiling point of the monomer is 100.3°C. The phase at which water is boiling, the exothermic temperature within the thick portion of the mass, exceeds the boiling of the residual monomer and such boiling causes voids which are trapped between the body of the mass, being unable to escape due to the already polymerized external surface. Thus, these voids remain as internal porosity. If by accident any water gets mixed with the monomer, the boiling point of the monomer will be lowered and the internal porosity will occur at a point below the boiling point of the water. Internal porosity of this nature is not noticed close to the edge because the sides of the flask readily carry away the exothermic heat.

Tuckfield, et.al., in 1943, indicated that polymerization proceeds from the outside going inwards.

In 1861, Anderson stated that the reaction proceeds from the outside going inwards and the first part to polymerize is that nearest to the source of heat.

In 1949, Harman measured the temperatures within the resin during various processing conditions. Twenty minutes after the flask was placed in a water bath at 160°F, the base material of a thick denture reached its environmental temperature. It remained at this temperature for 15 minutes then rose sharply to 278°F after 50 minutes in the water. At the end of 60 minutes, the temperature declined rapidly to that of the environment and remained at this level.

In 1959, Atkinson and Dennis measured the pressure inside the acrylic resin during polymerization and concluded that, the higher the bath temperature, the higher the internal temperature. They also observed that higher pressure prevented porosity. They also found that the maximum internal temperature was always considerably above that of the boiling point of the monomer.

In 1964, Atkinson and Grant, indicated that there is a difference in the thermal behavior of (poly)methyl methacrylate according to whether it is heated rapidly or slowly. With slow heating at a constant rate, the exothermic reaction commences in the center of the mass of resin and the heat produced is dissipated through the peripheral areas. Rapid heating with the exothermic reaction commencing at the periphery and moving inwards caused a build-up of heat and higher temperatures are recorded at the center of the specimen than with slow heating. It would appear, therefore, that the inward moving reaction is one of the causes of porosity. However, in an experiment in an air pressure chamber (Atkinson, 1959), using pressure of 100 psi., porosity was never produced even when the chamber was heated directly and the specimen placed immediately in boiling water.

If the supposition that internal porosity due to the evaporation of monomer is valid, then some gas should be found inside a resin preparation. On the other hand, if internal foams are cavities because of shrinkage, then they should be, at least immediately after preparation, in a state of approaching vacuum (Ohasi, 1961).

In 1952, Taka Yama, gave an analysis of the contents of foams generated inside methyl methacrylate resin. The inside gas consists chiefly of nitric gas with other ingredients such as oxygen, hydrogen, and other gasses. In relation to the passage of time, however, the amount of oxygen increased and finally approached that of ordinary air; the internal pressure being almost identical to the external pressure.

Ohasi, in 1961, attributes the occurance of internal porosity to incorporating air during mixing which becomes part of the resin material being contained in the process of preparation. This collects in the spots where the polymerization is late in setting because of changes in solubility and of curing heat, thus, resulting in the formation of shrinkage cavities and causing internal porosity.

Yet another type of porosity which is evident on the surface is caused by lack of sufficient pressure during the trial closure and while in the process of curing. The pressure during the trial closure is best attained, not by the help of the mechanical bench press, but by the correct consistency of the ~~dough-like~~ mix. A stringy mix when packed will spread without resistance and there will be a lack of pressure even after the final trial and trimming of the flash. An additional extra portion of dough should be packed and the case closed under heavy pressure. This extra mass pressure will compensate for the curing shrinkage and avoid porosity on the surface (Mewar, 1955).

The lack of homogenity in the dough or gel at the time of polymerization is another cause of porosity in an acrylic denture base. Phillips, in 1973, stated that although the dentist may follow the directions carefully in the preparation of the dough, complete homogenity of the mass is difficult to attain without an extensive mixing procedure, not generally feasible in the dental laboratory. It is probable that some regions will contain more monomer than others. These regions will shrink more during polymerization than the adjacent regions, and such localized shrinkage will tend to produce voids. The occurrance of such type of porosity can be minimized by insuring that the greatest possible homogenity of the resin gel is attained.

MATERIALS AND METHODS

Two processing techniques of Acrylic resin denture base materials were investigated. The conventional compression molding versus the dry heat-high pressure technique, using three different brands of heat-cure acrylic resins; Arnold[*], Duraflow[**], and Leucitone[***] acrylic resins with respect to:

a) Water sorption
b) Dehydration
c) Porosity , was evaluated

To standardize the thickness and size of the test specimens, three flat metal strips were made from aluminum according to the following measurements: 10mm width, 20mm length, and, subsequently, 1, 2, 3, mm thickness.

Compression Molding Technique

Plaster of Paris was mixed according to the manufacturer's directions and the metal moulds were invested in the lower half of the flask. After the investing material became hardened, soap solution was used as a separation medium. This was followed by pouring the top half of the flask in investment plaster.

After the investment was set, the two halves of the flask were opened. The metal moulds were carefully removed, thus creating a mould space of uniform thickness for the resin material.

The acrylic polymer and monomer were mixed according to the manufacturer's directions and Coe-Set[****] was used as a separating agent. When the acrylic mixture had reached the dough stage, the resin was packed into the mould cavity, and trial closures were done two times. The flask was then closed gradually under pressure which was maintained until the acrylic had been processed. Processing was carried out in the Hanau Curing[*****] Unit at 156°F for nine hours.

[*] Arden Acrylic Resin, Willmington, Del., 19803

[**] Duraflow Products Research Laboratories, Cambridge, Mass., 02193

[***] Leucitone. The L.D. Caulk Company, Milford, Del., 19963

[****] Coe Laboratories, Inc., Chicago, Ill.

[*****] Hanau Engineering Co., Buffalo, N.Y.

Dry Heat-High Pressure Technique

The method of flasking and packing was the same as for the control (Compression Moulding Technique) group. The difference was in the design of the flask. The flask used in the Dry Heat Technique consists of three parts: a solid bottom, a ring portion with a plunger hole in the back, and a cover (Fig. I). Before packing, a groove was ditched on the investment that connects the mould space through the opening in the back of the ring portion of the flask (Plunger Hole). The flask was then secured by three screws, one in the front and two in the back. Before processing, an extra piece of acrylic dough was put in the plunger hole and forced down with the plunger (Fig. II). The manufacturer introduced a new machine (Desnoyer's Press)* that works on the principle of heating the flask between two electrically heated plates while keeping the acrylic resin under hydraulic pressure during the entire processing period.

The machine consists of an enclosed metal cabinet 15" by 12" by 14", containing a heating element, hydraulic platen closure with a jack that pumps the pressure manually, pressure and temperature gauges, times switch, and an on/off switch (Fig. III).

As the machine is turned on, the temperature rises gradually until it reaches 265°F. At that time, the flask is inserted into the machine and pressure is applied manually by pumping the hydraulic jack. The alarm is set by a time switch which sounds after 15 minutes; the time necessary for curing. The acrylic is processed at 265°F under 20000 psi. The machine is turned off, pressure is released, and the flask is removed and left to cool on the bench.

* Desnoyer's Press, Firchburg, MA.

After deflasking, the specimens were recovered, cleaned off of investment particles, coded for identification, and then finished with burs, stones, rag wheel, and pumice. Finally, they were polished with a rag wheel and whitened under light pressure. The specimens were then cleaned off and dried.

Water Sorption Test

For this test, three samples, 1, 2, and 3 mm thickness, of each acrylic brand processed by the conventional compressions moulding technique and the dry heat technique were used.

The samples were first conditioned by placing them in a dessicater, which contained anhydrous calcium sulphate and weighed every day until two consistent readings were recorded. The specimens were then weighed every week for four weeks, and the change in weight was recorded. Weighing was carried out using Mettler H31 balance**, accurate to mgz.

Dehydration

Three samples of each thickness of the different acrylic brands, processed by both the conventional compression molding and the dry heat-high pressure techniques were tested. After the specimens had been finished and polished, they were weighed initially then stored in an open air and weighed every week for four weeks.

Porosity

Samples of the three different brands of acrylic resin, processed by both the conventional method and the dry heat-high pressure methods, were fractured. The resulting surfaces were examined after preparation by the scanning electron microscope.

** -Acit
Cram-Acit balance
Fissure Scientific, PA, N.Y., N.J.
Made in Switzerland, Mettler - Zurich

Preparation of the specimens for Scanning Electron Microscope

The specimens were attached to a metal stub using Duco cement, with the fractured surface facing up.

Silver paint was applied to improve conductivity.

The specimens were then sputter coated* with gold palladium to make the sample conductive. The specimens were then examined in the scanning electron microscope and photomicrographs** were taken.

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* Technics, Alexandria, Virginia

** Polaroid, Cambridge, Massachusetts

FIGURE I

Photograph of assembled flask for dry heat processing machine. Note the plunger hole in the back of the flask (See Arrow). This opening is connected to the mould cavity.

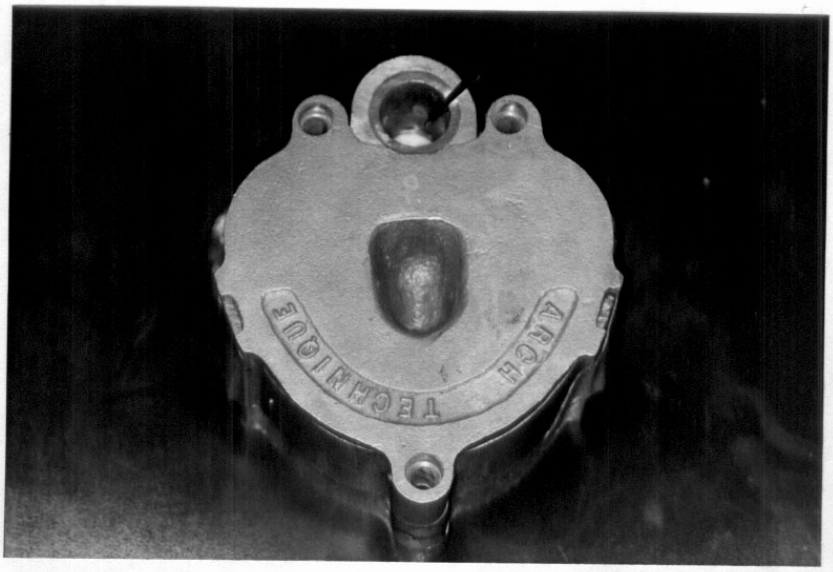


FIGURE II

Photograph of the assembled dry heat-high pressure special flask with its three components: bottom, ring, and cover.

1) Plunger metal piece
2) Tightening screws
3) Handle to tighten screws

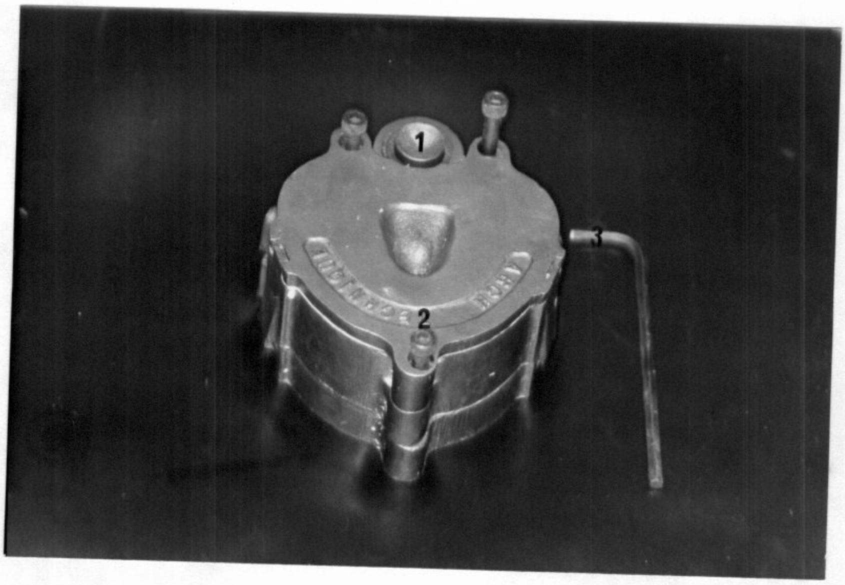
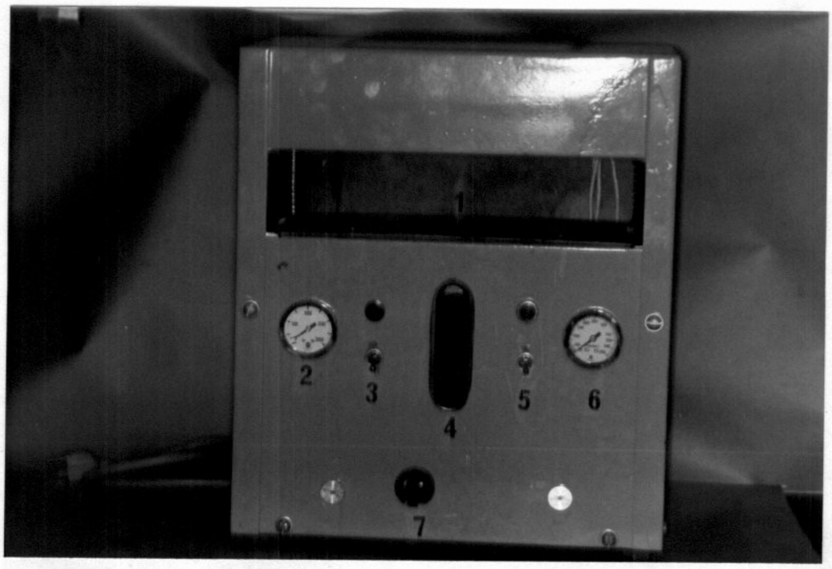


FIGURE III

Dry Heat-High Pressure Processing Machine (Desnoyer's Press)

1) Access opening to the heating plates
2) Pressure gauge
3) Buzzer
4) Opening for the jack that raises the pressure
5) On/Off switch
6) Temperature gauge
7) Pressure release valve



RESULTS

Water Sorption

The weight of the acrylic test samples, after being conditioned, was recorded. The specimens were then immersed in water and the weight change was recorded every week for four weeks, for each acrylic brand (i.e., Arnold, Duraflow, Leucitone acrylic resins) processed by both Compression Moulding technique (CMT) and the Dry-Heat technique (DHT). The results are shown in Tables 1 through 6.

The weight change was examined relative to:

a) The processing technique, i.e., Compression Moulding versus Dry Heat-High Pressure technique.

b) Effect of material, i.e., type of acrylic brand (Arnold, Duraflow, and Leucitone acrylic resins).

c) Effect of sample thicknes - 1, 2, 3 mm.

A comparison was made between the original weights and the weight after 28 days for each sample processed by both the Compression Moulding technique (CMT) and the Dry Heat technique. The percentage increase in weight for each acrylic brand are shown in Tables VII through XII.

Table XIII summarizes the comparison between all acrylic brands processed by both techniques regarding the percentage of the overall increase in weight.

Effect of Processing Technique

A comparison of weight gains, due to water sorption test, among samples processed by two techniques, i.e., the Compression Moulding technique (CMT) and the Dry Heat technique (DHT), was done by a two way factor analysis of variance (The K-Way Method).

Two factors were used to analyze the weight gains for significance due to the processing technique including: 1) thickness of sample; and 2) processing technique for sample. In addition, an interaction factor (between both factors was given. From the analysis of variance, an F-ratio was calculated (F-ratio = MS Factor/MS Error) for each factor examined.

FACTOR	F-RATIO	D O F	F-VALUE	α at 0.005	SIGNIFICANCE
Thickness	$\frac{0.00224456}{0.00000136}$	$\frac{2}{48}$	1603.3	5.93	Yes
Technique	$\frac{0.00000451}{0.00000136}$	$\frac{1}{48}$	3.214	8.66	No

Here, as in all other tests, the significance of each factor is examined by comparison of the F-Value to the corresponding α at the upper 0.5% of the F-distribution. Other information can be obtained from the test, such as means of weight gain according to the thickness, the pooled estimate of the standard deviation, and sample variance can be calculated.

Effect of Material and Effect of Thickness on Weight Gain

A comparison of weight gains, due to the water sorption test, among samples made of three different brands was done by a two way factor analysis of variance (The K-Way Method).

Two factors were used to analyze the weight gains for significance:

1) Thickness of sample 1, 2, or 3 mm

2) Sample material (Arnold, Duraflow, or Leucitone arylic resins)

Interaction between these two factors is also examined.

(A) Compression Moulding Technique

FACTOR	F-RATIO	D O F	F-VALUE	α at 0.005	SIGNIFICANCE
Thickness	$\frac{0.001080221}{0.000000071}$	$\frac{2}{18}$	10802.0	7.21	Yes
Material	$\frac{0.000011748}{0.000000071}$	$\frac{2}{18}$	117.0	7.21	Yes
Interaction	$\frac{0.000000889}{0.000000071}$	$\frac{4}{18}$	9.0	5.37	Yes

Examination of the data showed lower weight gain for Duraflow samples within the compression moulding technique than for Arnold or Leucitone acrylic resins.

(B) Dry Heat Technique Only

FACTOR	F-RATIO	D O F	F-VALUE	α at 0.005	SIGNIFICANCE
Thickness	$\frac{0.001165168}{0.0000001}$	$\frac{2}{18}$	11652	7.21	Yes
Material	$\frac{0.000014943}{0.0000001}$	$\frac{2}{18}$	149	7.21	Yes
Interaction	$\frac{0.000001294}{0.0000001}$	$\frac{4}{18}$	13	5.37	Yes

Examination of the data indicates that a generally lower weight gain for Duraflow samples than for Arnold or Leucitone acrylic resins appear as in (A).

(C) Compression Moulding Technique and Dry Heat Technique for weight gain are pooled in this test and the results are the same as in both (A) and (B) analysis of variance.

FACTOR	F-RATIO	D O F	F-VALUE	α at 0.005	SIGNIFICANCE
Thickness	$\frac{0.002244560}{0.00000023}$	$\frac{2}{45}$	11223	5.97	Yes
Material	$\frac{0.000026576}{0.00000023}$	$\frac{2}{45}$	133	5.97	Yes
Interaction	$\frac{0.000001968}{0.00000023}$	$\frac{4}{45}$	9	4.25	Yes

TABLE I

Water Sorption Test

Weight gain of Arnold Acrylic Resin processed by Compression Moulding Technique

Thickness	Sample Code	Original Weight	Water Sorption in 7 days	Water Sorption in 14 days	Water Sorption in 21 days	Water Sorption in 28 days
1mm	A	0.6020	0.6110	0.6125	0.6129	0.6130
	B	0.5969	0.6063	0.6072	0.6076	0.6077
	C	0.5961	0.6055	0.6064	0.6069	0.6068
2mm	D	1.2044	1.2228	1.2258	1.2264	1.2266
	E	1.2014	1.2203	1.2229	1.2234	1.2235
	F	1.2107	1.2290	1.2323	1.2330	1.2331
3mm	G	1.7787	1.8064	1.8108	1.8121	1.8123
	H	1.7769	1.8046	1.8089	1.8102	1.8104
	I	1.7942	1.8227	1.8267	1.8181	1.8282

TABLE II

Water Sorption Test

Weight gain of Arnold Acrylic Resin processed by Dry Heat Technique

Thickness	Sample Code	Original Weight	Water Sorption in 7 days	Water Sorption in 14 days	Water Sorption in 21 days	Water Sorption in 28 days
1mm	L	0.6166	0.6276	0.6280	0.6281	0.6281
	M	0.6036	0.6138	0.6144	0.6148	0.6147
	N	0.6062	0.6165	0.6170	0.6173	0.6174
2mm	O	1.2178	1.2391	1.2400	1.2407	1.2409
	P	1.2034	1.2239	1.2249	1.2258	1.2260
	Q	1.2209	1.2423	1.2434	1.2440	1.2441
3mm	R	1.7947	1.8256	1.8284	1.8290	1.8294
	S	1.7822	1.8125	1.8155	1.8161	1.8163
	T	1.7883	1.8189	1.8219	1.8225	1.8227

TABLE III

Water Sorption Test

Water gain of Duraflow Acrylic Resin processed by Compression Moulding Technique

Thickness	Sample Code	Original Weight	Water Sorption in 7 days	Water Sorption in 14 days	Water Sorption in 21 days	Water Sorption in 28 days
1mm	P	0.6139	0.6220	0.6235	0.6239	0.6240
	V	0.5855	0.5930	0.5938	0.5945	0.5948
	C	0.5960	0.6040	0.6053	0.6057	0.6057
2mm	S	1.2116	1.2282	1.2308	1.2314	1.2318
	L	1.2075	1.2246	1.2268	1.2273	1.2275
	O	1.2151	1.2320	1.2346	1.2353	1.2355
3mm	K	1.7858	1.8122	1.8151	1.8162	1.8164
	E	1.7783	1.8042	1.8072	1.8083	1.8085
	M	1.7839	1.8103	1.8132	1.8143	1.8144

TABLE IV

Water Sorption Test

Water gain of Duraflow Acrylic Resin processed by Dry Heat Technique

Thickness	Sample Code	Original Weight	Water Sorption in 7 days	Water Sorption in 14 days	Water Sorption in 21 days	Water Sorption in 28 days
1mm	L	0.6072	0.6165	0.6170	0.6173	0.6174
	U	0.5824	0.5914	0.5916	0.5918	0.5919
	C	0.5856	0.5945	0.5949	0.5951	0.5952
2mm	K	1.2121	1.2309	1.2317	1.2324	1.2327
	N	1.2163	1.2350	1.2360	1.2368	1.2370
	P	1.2213	1.2401	1.2412	1.2420	1.2421
3mm	A	1.7858	1.8141	1.8165	1.8171	1.8169
	C	1.7706	1.7984	1.8008	1.8014	1.8012
	D	1.7940	1.8227	1.8243	1.8254	1.8255

TABLE V

Water Sorption Test

Water gain of Leucitone Acrylic Resin processed by Compression Moulding Technique

Thickness	Sample Code	Original Weight	Water Sorption in 7 days	Water Sorption in 14 days	Water Sorption in 21 days	Water Sorption in 28 days
1mm	P	0.6034	0.6121	0.6135	0.6139	0.6139
	L	0.6164	0.6252	0.6264	0.6270	0.6273
	A	0.6174	0.6267	0.6282	0.6284	0.6284
2mm	S	1.1990	1.2175	1.2197	1.2205	1.2206
	T	1.2175	1.2359	1.2387	1.2397	1.2398
	E	1.2034	1.2215	1.2240	1.2249	1.2251
3mm	R	1.7825	1.8097	1.8142	1.8152	1.8154
	O	1.7910	1.8188	1.8231	1.8242	1.8242
	K	1.7793	1.8064	1.8109	1.8118	1.8120

TABLE VI

Water Sorption Test

Water gain of Leucitone Acrylic Resin processed by Dry Heat Technique

Thickness	Sample Code	Original Weight	Water Sorption in 7 days	Water Sorption in 14 days	Water Sorption in 21 days	Water Sorption in 28 days
1mm	A	0.5848	0.5948	0.5950	0.5952	0.5953
	C	0.5889	0.5987	0.5991	0.5994	0.5995
	R	0.5971	0.6076	0.6075	0.6078	0.6079
2mm	Y	1.2061	1.2265	1.2274	1.2283	1.2284
	L	1.2272	1.2480	1.2490	1.2500	1.2502
	I	1.2157	1.2364	1.2377	1.2383	1.2383
3mm	S	1.7980	1.8305	1.8319	1.8328	1.8329
	U	1.7862	1.8185	1.8198	1.8204	1.8206
	P	1.7802	1.8132	1.8135	1.8141	1.8143

TABLE VII

Water Sorption Test

The mean $\bar{x}$ increase in weight of Arnold Acrylic Resin processed by Compression Moulding Technique after 28 days

Thickness	Sample Code	Original Weight	28 day Weight	Difference (gain)	% Increase Weight
1mm	A	.6020	.6130	.0110	1.79
	B	.5969	.6077	.0108	1.78
	C	.5961	.6068	.0107	1.76
mean $\bar{x}$				$\bar{x}$=.0108	$\bar{x}$=1.78
2mm	D	1.2044	1.2266	.0222	1.809
	E	1.2014	1.2235	.0221	1.806
	F	1.2107	1.2331	.0224	1.817
mean $\bar{x}$				$\bar{x}$=.0222	$\bar{x}$=1,811
3mm	G	1.7787	1.8123	.0336	1.85
	H	1.7769	1.8104	.0335	1.85
	I	1.7942	1.8282	.034	1.86
mean $\bar{x}$				$\bar{x}$=.0337	$\bar{x}$=1.85

TABLE VIII

Water Sorption Test

The mean $\bar{x}$ increase in weight of Arnold Acrylic Resin processed by Dry Heat Technique after 28 days

Thickness	Sample Code	Original Weight	28 day Weight	Difference (gain)	% Increase Weight
	L	.6166	.6281	.0115	1.83
1mm	M	.6036	.6147	.0111	1.81
	N	.6062	.6174	.0112	1.81
mean $\bar{x}$				$\bar{x}$=.0113	$\bar{x}$=1.82
	O	1.2178	1.2409	.0231	1.86
2mm	P	1.2034	1.2260	.0226	1.84
	Q	1.2209	1.2441	.0232	1.86
mean $\bar{x}$				$\bar{x}$=.0230	$\bar{x}$=1.85
	R	1.7947	1.8294	.0347	1.90
3mm	S	1.7822	1.8163	.0341	1.88
	T	1.7883	1.8227	.0344	1.89
mean $\bar{x}$				$\bar{x}$=.0334	$\bar{x}$=1.89

TABLE IX

Water Sorption Test

The mean $\bar{x}$ increase in weight of Duraflow Acrylic Resin processed by Compression Moulding Technique after 28 days

Thickness	Sample Code	Original Weight	28 day Weight	Difference (gain)	% Increase Weight
1mm	P	.6139	.6240	.0101	1.62
	V	.5855	.5948	.0093	1.56
	C	.5960	.6057	.0097	1.60
mean $\bar{x}$				$\bar{x}$=.0097	$\bar{x}$=1.59
2mm	S	1.2116	1.2318	.0202	1.64
	L	1.2075	1.2275	.020	1.63
	O	1.2151	1.2355	.0204	1.65
mean $\bar{x}$				$\bar{x}$=.0202	$\bar{x}$=1.64
3mm	K	1.7858	1.8164	.0306	1.68
	E	1.7783	1.8085	.0302	1.67
	M	1.7839	1.8144	.0305	1.68
mean $\bar{x}$				$\bar{x}$=.0304	$\bar{x}$=1.68

TABLE X

Water Sorption Test

The mean $\bar{x}$ increase in weight of Duraflow Acrylic Resin processed by Dry Heat Technique after 28 days

Thickness	Sample Code	Original Weight	28 day Weight	Difference (gain)	% Increase Weight
1mm	L	.6072	.6174	.0102	1.65
	V	.5824	.5919	.0095	1.61
	C	.5856	.5952	.0096	1.61
mean $\bar{x}$				$\bar{x}$=.0098	$\bar{x}$=1.62
2mm	K	1.2121	1.2327	.0206	1.67
	N	1.2163	1.2370	.0207	1.67
	P	1.2213	1.2421	.0208	1.67
mean $\bar{x}$				$\bar{x}$=.0207	$\bar{x}$=1.67
3mm	A	1.7858	1.8169	.0311	1.71
	C	1.7706	1.8012	.0306	1.70
	D	1.7940	1.8255	.0315	1.73
mean $\bar{x}$				$\bar{x}$=.0311	$\bar{x}$=1.71

TABLE XI

Water Sorption Test

The mean $\bar{x}$ increase in weight of Leucitone Acrylic Resin processed by Compression Moulding Technique after 28 days

Thickness	Sample Code	Original Weight	28 day Weight	Difference (gain)	% Increase Weight
1mm	P	.6034	.6139	.0105	1.71
	L	.6164	.6273	.0109	1.74
	A	.6174	.6284	.0110	1.75
mean $\bar{x}$				$\bar{x}$=.0108	$\bar{x}$=1.73
2mm	S	1.1990	1.2206	.0216	1.77
	T	1.2175	1.2398	.0223	1.80
	E	1.2034	1.2251	.0217	1.77
mean $\bar{x}$				$\bar{x}$=.0219	$\bar{x}$=1.78
3mm	R	1.7825	1.8154	.0329	1.81
	O	1.7910	1.8242	.0332	1.82
	K	1.7793	1.8120	.0327	1.80
mean $\bar{x}$				$\bar{x}$=.0329	$\bar{x}$=1.81

TABLE XII

Water Sorption Test

The mean $\bar{x}$ increase in weight of Leucitone Acrylic Resin processed by Dry Heat Technique after 28 days

Thickness	Sample Code	Original Weight	28 day Weight	Difference (gain)	% Increase (Weight)
	A	.5848	.5953	.0105	1.76
1mm	C	.5889	.5995	.0106	1.77
	R	.5971	.6079	.0108	1.78
mean $\bar{x}$				$\bar{x}$=.0106	$\bar{x}$=1.77
	Y	1.2061	1.2284	.0223	1.82
2mm	L	1.2272	1.2502	.0230	1.84
	I	1.2157	1.2383	.0226	1.83
mean $\bar{x}$				$\bar{x}$=.0226	$\bar{x}$=1.83
	S	1.7980	1.8329	.0349	1.90
3mm	V	1.7862	1.8206	.0344	1.89
	P	1.7802	1.8143	.0341	1.88
mean $\bar{x}$				$\bar{x}$=.0345	$\bar{x}$=1.89

TABLE XIII

Comparison of the over all percentage increase in weight (all thickness) for both processing Techniques

Acrylic Brand	Compression Moulding Technique	Dry Heat Technique
Arnold	1.814%	1.853%
Duraflow	1.637%	1.667%
Leucitone	1.773%	1.830%

Dehydration

The weight of the acrylic test samples, after being finished and polished, was recorded. Then the specimens were left to dry out and the weight loss was recorded every week for four weeks for each acrylic brand, i.e., Arnold, Duraflow, and Leucitone acrylic resins, processed by both Compression Moulding technique (CMT) and Dry Heat technique (DHT). The results are shown in tables 14 through 19.

The weight loss was examined relative to:

a) The processing technique, i.e., Compression Moulding versus Dry Heat-High Pressure processing technique.

b) Effect of material, i.e., type of acrylic brand (Arnold, Duraflow, and Leucitone acrylic resins).

c) Effect of sample thickness - 1, 2, 3, mm.

A comparison was made between the original weight and the weight after 28 days for each sample processed by both the Compression Moulding technique and the Dry Heat technique. The percentage decrease in weight for each acrylic brand is shown in tables XX through XXV. Table XXVI summarizes the comparison between all acrylic brands processed by both techniques regarding the percentage of the overall loss in weight.

Effect of Processing Technique

A comparison of weight losses, due to a dehydration test among samples processed by the two processing techniques, i.e., CMT and DHT, was done in exactly the same way as in the previous test.

FACTOR	F-RATIO	D O F	F-VALUE	α at 0.005	SIGNIFICANCE
Thickness	$\frac{0.000333147}{0.000000673}$	$\frac{2}{48}$	476.0	5.93	Yes
Technique	$\frac{0.000002449}{0.000000673}$	$\frac{1}{48}$	3.43	8.66	No

Effect of Material, Effect of Thickness, and Weight Loss

A comparison of weight losses, due to a dehydration test among samples made of three different acrylic brands was done by a two-way factor analysis of variance.

Two factors were used to analyse the weight loss for significance:

1) Sample thickness
2) Sample material (type of acrylic brand)

(A) Compression Moulding Technique Only

FACTOR	F-RATIO	D O F	F-VALUE	α at 0.005	SIGNIFICANCE
Thickness	$\frac{0.000166558}{0.000000183}$	$\frac{2}{18}$	1666	7.21	Yes
Material	$\frac{0.000005885}{0.000000183}$	$\frac{2}{18}$	59	7.21	Yes
Interaction	$\frac{0.000000639}{0.000000183}$	$\frac{4}{18}$	3	5.37	No

(B) Dry Heat Technique Only

FACTOR	F-RATIO	D O F	F-VALUE	α at 0.005	SIGNIFICANCE
Thickness	$\frac{0.000166589}{0.000000133}$	$\frac{2}{18}$	1666	7.21	Yes
Material	$\frac{0.000005335}{0.000000133}$	$\frac{2}{18}$	53	7.21	Yes
Interaction	$\frac{0.000000404}{0.000000133}$	$\frac{4}{18}$	4	5.37	No

For both A) and B), the Leucitone appears to experience less weight loss than Arnold, which is less than Duraflow in the pooled test as well as in C).

C)

FACTOR	F-RATIO	D O F	F-VALUE	α at 0.005	SIGNIFICANCE
Thickness	$\frac{0.000333147}{0.000000184}$	$\frac{2}{45}$	1665	5.97	Yes
Material	$\frac{0.000011187}{0.000000184}$	$\frac{2}{45}$	56	5.97	Yes
Interaction	$\frac{0.000001017}{0.000000184}$	$\frac{2}{45}$	5	4.25	No

TABLE XIV

Dehydration Test

Weight loss of Arnold Acrylic Resin processed by Compression Moulding Technique

Thickness	Sample Code	Original Weight	Weight loss after 7 days	Weight loss after 14 days	Weight loss after 21 days	Weight loss after 28 days
1mm	C	0.5891	0.5847	0.5841	0.5838	0.5839
	O	0.6026	0.5994	0.5984	0.5982	0.5980
	D	0.6004	0.5970	0.5961	0.5959	0.5957
2mm	K	1.2061	1.1972	1.1967	1.1964	1.1963
	I	1.2187	1.2113	1.2103	1.2098	1.2097
	R	1.2107	1.2026	1.2018	1.2014	1.2012
3mm	L	1.7832	1.7703	1.7697	1.7693	1.7692
	Y	1.7954	1.7842	1.7828	1.7823	1.7824
	Z	1.7941	1.7826	1.7815	1.7810	1.7809

TABLE XV

Dehydration Test

Weight loss of Arnold Acrylic Resin processed by Dry Heat Technique

Thickness	Sample Code	Original Weight	Weight loss in 7 days	Weight loss in 14 days	Weight loss in 21 days	Weight loss in 28 days
1mm	S	0.6022	0.5982	0.5977	0.5976	0.5975
	T	0.6072	0.6042	0.6032	0.6028	0.6028
	A	0.6033	0.5996	0.5991	0.5993	0.5987
2mm	R	1.2016	1.1932	1.1923	1.1919	1.1918
	V	1.2141	1.2074	1.2060	1.2054	1.2053
	I	1.2114	1.2045	1.2033	1.2028	1.2026
3mm	E	1.7878	1.7775	1.7755	1.7748	1.7749
	W	1.7821	1.7709	1.7692	1.7687	1.7686
	N	1.7928	1.7835	1.7811	1.7804	1.7803

TABLE XVI

Dehydration Test

Weight loss of Duraflow Acrylic Resin processed by Compression Moulding Technique

Thickness	Sample Code	Original Weight	Weight Loss in 7 days	Weight Loss in 14 days	Weight Loss in 21 days	Weight Loss in 28 days
1mm	E	0.6130	0.6085	0.6080	0.6078	0.6077
	R	0.6043	0.5990	0.5989	0.5990	0.5088
	C	0.6011	0.5959	0.5956	0.5955	0.5955
2mm	D	1.2107	1.2020	1.2012	1.2006	1.2006
	K	1.2046	1.1950	1.1945	1.1943	1.1942
	F	1.2015	1.1917	1.1913	1.1910	1.1909
3mm	O	1.7827	1.7684	1.7680	1.7673	1.7671
	P	1.7987	1.7860	1.7852	1.7845	1.7845
	T	1.7844	1.7703	1.7696	1.7690	1.7690

TABLE XVII

Dehydration Test

Weight loss of Duraflow Acrylic Resin processed by Dry Heat Technique

Thickness	Sample Code	Original Weight	Weight Loss in 7 days	Weight Loss in 14 days	Weight Loss in 21 days	Weight Loss in 28 days
1mm	S	0.5863	0.5820	0.5811	0.5812	0.5811
	P	0.5816	0.5771	0.5766	0.5764	0.5763
	I	0.6044	0.6016	0.6004	0.5998	0.5998
2mm	L	1.2083	1.1997	1.1985	1.1983	1.1981
	U	1.2109	1.2032	1.2019	1.2014	1.2011
	T	1.2136	1.2063	1.2048	1.2041	1.2040
3mm	K	1.7906	1.7785	1.7769	1.7765	1.7763
	E	1.7856	1.7731	1.7712	1.7709	1.7707
	M	1.7924	1.7814	1.7192	1.7784	1.7783

TABLE XVIII

Dehydration Test

Weight loss of Leucitone Acrylic Resin processed by Compression Moulding Technique

Thickness	Sample Code	Original Weight	Weight Loss in 7 days	Weight Loss in 14 days	Weight Loss in 21 days	Weight Loss in 28 days
1mm	A	0.6178	0.6140	0.6134	0.6132	0.6132
	B	0.6155	0.6114	0.6111	0.6111	0.6109
	C	0.5897	0.5850	0.5847	0.5848	0.5846
2mm	R	1.2039	1.1956	1.1949	1.1948	1.1947
	O	1.2162	1.2093	1.2083	1.2078	1.2077
	K	1.2114	1.2035	1.2026	1.2028	1.2026
3mm	L	1.7817	1.7705	1.7697	1.7694	1.7693
	M	1.7834	1.7728	1.7717	1.7710	1.7711
	N	1.7792	1.7671	1.7669	1.7665	1.7665

TABLE XIX

Dehydration Test

Weight Loss of Leucitone Acrylic Resin processed by Dry Heat Technique

Thickness	Sample Code	Original Weight	Weight Loss in 7 days	Weight Loss in 14 days	Weight Loss in 21 days	Weight Loss in 28 days
1mm	X	0.5917	0.5883	0.5877	0.5875	0.5874
	Y	0.5942	0.5915	0.5906	0.5901	0.5901
	Z	0.5952	0.5930	0.5917	0.5913	0.5912
2mm	O	1.2030	1.1969	1.1953	1.1952	1.1950
	P	1.1984	1.1914	1.1903	1.1900	1.1898
	L	1.1994	1.1925	1.1912	1.1909	1.1908
3mm	M	1.7835	1.7740	1.7721	1.7716	1.7715
	E	1.7795	1.7690	1.7677	1.7672	1.7671
	R	1.7819	1.7721	1.7704	1.7701	1.7698

TABLE XX

Dehydration Test

The mean $\bar{x}$ loss of weight of Arnold Acrylic Resin processed by Compression Moulding Technique after 28 days

Thickness	Sample Code	Original Weight	28 day Weight	Difference (loss)	% Decrease Weight
1mm	C	0.5891	0.5839	0.0052	0.88
	O	0.6026	0.5980	0.0046	0.76
	D	0.6004	0.5957	0.0047	0.78
mean $\bar{x}$				$\bar{x}$=0.0048	$\bar{x}$=0.81
2mm	K	1.2061	1.1963	0.0098	0.81
	I	1.2187	1.2097	0.0090	0.75
	R	1.2107	1.2012	0.0095	0.78
mean $\bar{x}$				$\bar{x}$=0.0094	$\bar{x}$=0.78
3mm	L	1.7832	1.7692	0.0140	0.79
	Y	1.7954	1.7824	0.0130	0.72
	Z	1.7941	1.7809	0.0132	0.74
mean $\bar{x}$				$\bar{x}$=0.0134	$\bar{x}$=0.75

TABLE XXI

Dehydration Test

The mean $\bar{x}$ loss of weight of Arnold Acrylic Resin
processed by Dry Heat Technique after 28 days

Thickness	Sample Code	Original Weight	28 day Weight	Difference (loss)	% Decrease Weight
1mm	S	0.6022	0.5975	0.0047	0.78
	T	0.6072	0.6028	0.0044	0.72
	A	0.6033	0.5987	0.0046	0.76
mean $\bar{x}$				$\bar{x}$=0.0046	$\bar{x}$=0.75
2mm	R	1.2016	1.1918	0.0098	0.82
	V	1.2141	1.2053	0.0088	0.72
	L	1.2114	1.2026	0.0088	0.73
mean $\bar{x}$				$\bar{x}$=0.0091	$\bar{x}$=0.75
3mm	E	1.7878	1.7749	0.0129	0.72
	W	1.7821	1.7686	0.0135	0.76
	N	1.7928	1.7803	0.0125	0.70
mean $\bar{x}$				$\bar{x}$=0.0129	$\bar{x}$=0.73

TABLE XXII

Dehydration Test

The mean $\bar{x}$ loss of weight of Duraflow Acrylic Resin processed by Compression Moulding Technique after 28 days

Thickness	Sample Code	Original Weight	28 day Weight	Difference (loss)	% Decrease Weight
1mm	E	0.6130	0.6077	0.0053	0.86
	R	0.6043	0.5988	0.0055	0.91
	C	0.6011	0.5955	0.0056	0.93
mean $\bar{x}$				$\bar{x}$=0.0055	$\bar{x}$=0.90
2mm	D	1.2107	1.2006	0.0101	0.83
	K	1.2046	1.1942	0.0104	0.86
	F	1.2015	1.1909	0.0106	0.88
mean $\bar{x}$				$\bar{x}$=0.0104	$\bar{x}$=0.86
3mm	O	1.7827	1.7671	0.0156	0.88
	P	1.7987	1.7847	0.0140	0.78
	T	1.7844	1.7690	0.0154	0.86
mean $\bar{x}$				$\bar{x}$=0.0150	$\bar{x}$=0.84

TABLE XXIII

Dehydration Test

The mean $\bar{x}$ loss of weight of Duraflow Acrylic Resin processed by Dry Heat Technique after 28 days

Thickness	Sample Code	Original Weight	28 day Weight	Difference (loss)	% Decrease Weight
1mm	S	0.5863	0.5811	0.0052	0.87
	P	0.5816	0.5763	0.0053	0.91
	L	0.6044	0.5998	0.0046	0.76
mean $\bar{x}$				$\bar{x}$=0.0050	$\bar{x}$=0.85
2mm	L	1.2083	1.1981	0.0102	0.84
	U	1.2109	1.2011	0.0098	0.81
	T	1.2136	1.2040	0.0096	0.79
mean $\bar{x}$				$\bar{x}$=0.0099	$\bar{x}$=0.81
3mm	K	1.7906	1.7763	0.0143	0.80
	E	1.7856	1.7707	0.0149	0.83
	M	1.7924	1.7783	0.0141	0.79
mean $\bar{x}$				$\bar{x}$=0.0144	$\bar{x}$=0.81

TABLE XXIV

Dehydration Test

The mean $\bar{x}$ loss of weight of Leucition Acrylic Resin processed by Compression Moulding Technique after 28 days

Thickness	Sample Code	Original Weight	28 day Weight	Difference (loss)	% Decrease Weight
1mm	A	0.6178	0.6132	0.0046	0.74
	B	0.6155	0.6109	0.0046	0.75
	C	0.5897	0.5846	0.0051	0.86
mean $\bar{x}$				$\bar{x}$=0.0048	$\bar{x}$=0.78
2mm	R	1.2039	1.1947	0.0092	0.76
	O	1.2162	1.2077	0.0085	0.70
	K	1.2114	1.2026	0.0088	0.73
mean $\bar{x}$				$\bar{x}$=0.0088	$\bar{x}$=0.73
3mm	L	1.7817	1.7693	0.0124	0.70
	M	1.7834	1.7711	0.0123	0.69
	N	1.7792	1.7665	0.0127	0.71
mean $\bar{x}$				$\bar{x}$=0.0125	$\bar{x}$=0.70

TABLE XXV

Dehydration Test

The mean $\bar{x}$ loss of weight of Leucitone Acrylic Resin processed by Dry Heat Technique after 28 days

Thickness	Sample Code	Original Weight	28 day Weight	Difference (loss)	% Decrease Weight
1mm	X	0.5917	0.5874	0.0043	0.73
	Y	0.5942	0.5901	0.0041	0.69
	Z	0.5952	0.5912	0.0041	0.69
mean $\bar{x}$				$\bar{x}$=0.0042	$\bar{x}$=0.70
2mm	O	1.2030	1.1950	0.0080	0.67
	P	1.1984	1.1898	0.0086	0.72
	L	1.1994	1.1908	0.0086	0.72
mean $\bar{x}$				$\bar{x}$=0.0084	$\bar{x}$=0.70
3mm	M	1.7835	1.7715	0.0120	0.67
	E	1.7795	1.7671	0.0124	0.70
	R	1.7819	1.7698	0.0121	0.70
mean x				$\bar{x}$=0.0122	$\bar{x}$=0.69

0.697% decrease overall

TABLE XXVI

Comparison of the over all percentage loss in weight
(all thickness) for both processing Techniques

Acrylic Brand	Compression Moulding Technique	Dry Heat Technique
Arnold	0.780%	0.743%
Duraflow	0.867%	0.823%
Leucitone	0.737%	0.697%

Porosity

Examination of the scanning electron microscope photomicrographs of the fractured acrylic samples, showed that acrylic resin processed by either technique provided a dense structure generally with no significant porosity except in the Leucitone 3mm thickness processed by the Dry Heat Technique.

I. Compression Moulding Technique

A. Arnold

There seems to be complete polymerization with a dense structure, although there is very minute porosity (Figure 5 through 7).

B. Duraflow

The polymer spheres can be clearly delineated. The matrix shows a non-homogenous structure (see arrows; Figure 8 through 10), but there is no porosity. Also some of the coloring fibers are shown in Figure 11.

C. Leucitone

The matrix looks very dense with a more compact scaley structure. There are very small areas of porosity which are maintained in both the 2mm and the 3mm thickness (Figures 12, 13, and 14).

II. Dry Heat-High Pressure Technique

A. Arnold

The matrix shows a very dense structure with no evidence of porosity (Figure 15 through 17).

B. Duraflow

The matrix is non-homogenous as in the Compression Moulding Technique (material related problem). The polymer spheres can be outlined clearly (see arrow), but there seems to be dissolution of the small ones with the matrix, showing some porosity maintained in the 2mm and the 3mm thickness (Figure 18 through 20).

C. Leucitone

The material seems to be dense with a few voids in the 1mm and the 2mm thickness (Figure 21 and 22). There is gross porosity in the 3mm thickness (See arrows; Figure 23).

FIGURE 4

Photomicrograph of Arnold acrylic resin processed by the conventional Compression Moulding Technique.
(1mm thick, 1000X, 10KV)

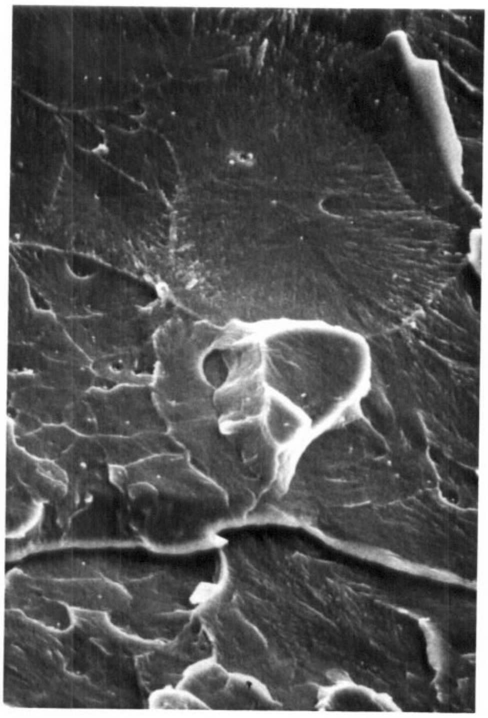


FIGURE 5

Photomicrograph of Arnold acrylic resin processed by the conventional Compression Moulding Technique.
(2mm thick, 1000X, 10KV)

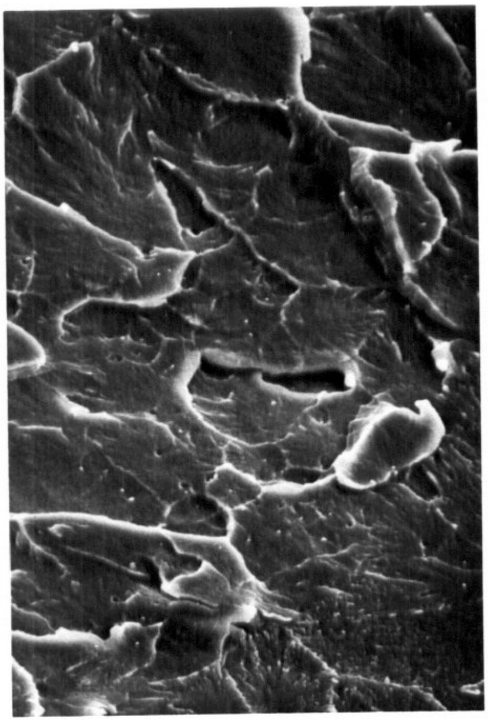


FIGURE 6

Photomicrograph of Arnold acrylic resin processed by the conventional Compression Moulding Technique.
(3mm thick, 1000X, 10KV)

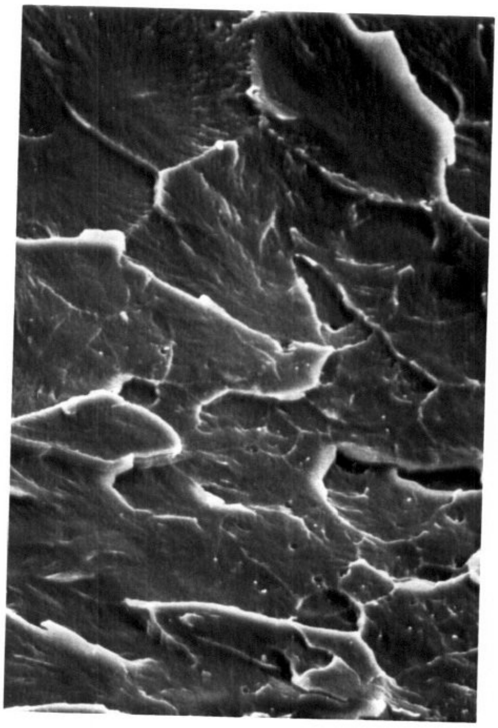


FIGURE 7

Photomicrograph of Duraflow acrylic resin processed by the conventional Compression Moulding Technique.
(1mm thick, 300X, 10KV)

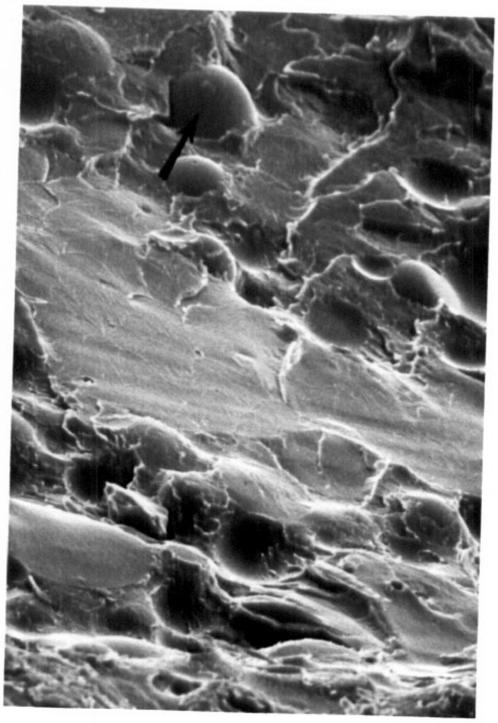


FIGURE 8

Photomicrograph of Duraflow acrylic resin processed by the conventional Compression Moulding Technique.
(2mm thick, 300X, 10KV)

FIGURE 9

Photomicrograph of Duraflow acrylic resin processed by the conventional Compression Moulding Technique.
(3mm thick, 300X, 10KV)

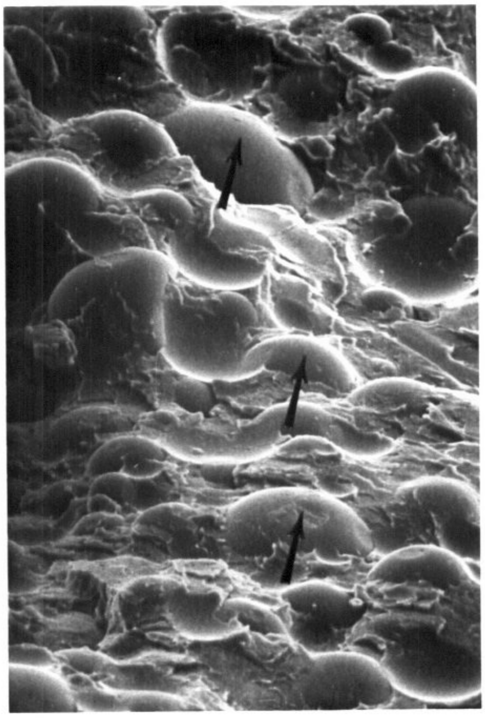


FIGURE ID

Photomicrograph of Duraflow acrylic resin processed by the conventional Compression Moulding Technique.
(2mm thick, 100X, 10KV)

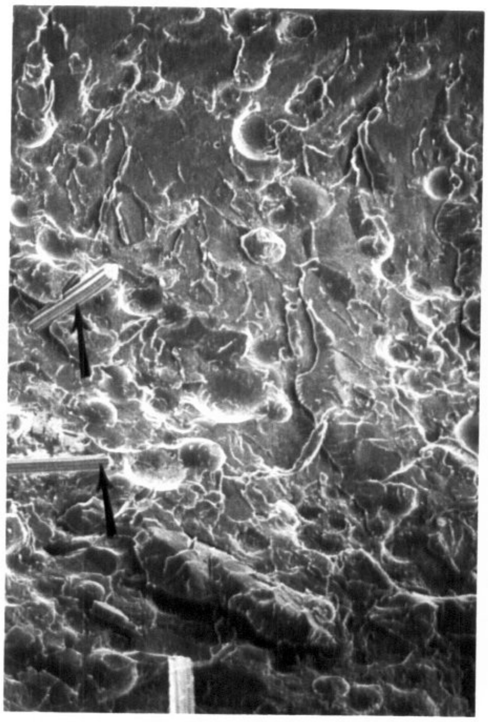


FIGURE 11

Photomicrograph of Leucitone acrylic resin processed by the conventional Compression Moulding Technique.
(1mm thick, 1000X, 10KV)

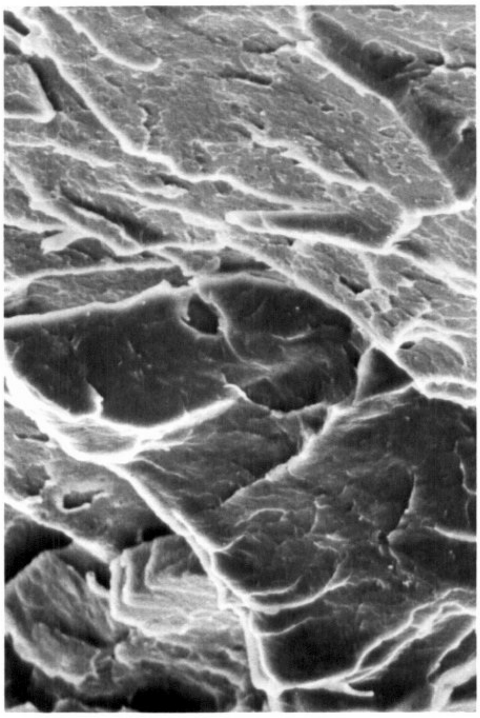


FIGURE 12

Photomicrograph of Leucitone acrylic resin processed by the conventional Compression Moulding Technique.
(2mm thick, 1000X, 10K V)

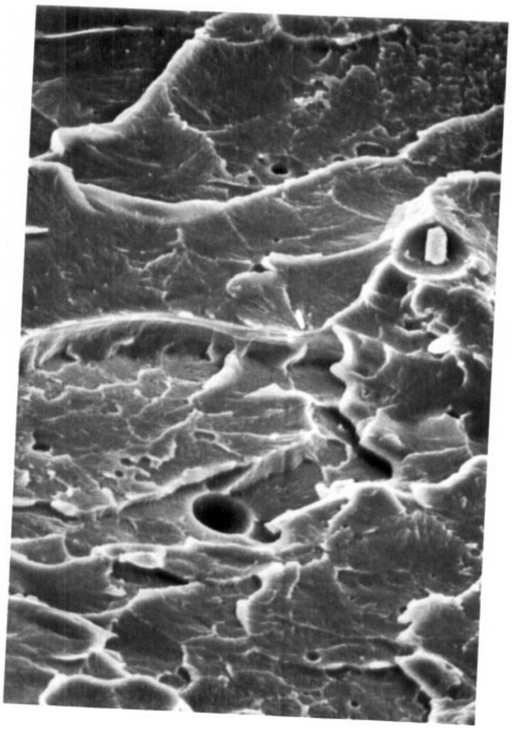


FIGURE 13

Photomicrograph of Leucitone acrylic resin processed by the conventional Compression Moulding Technique.
(3mm thick, 1000X, 10KV)

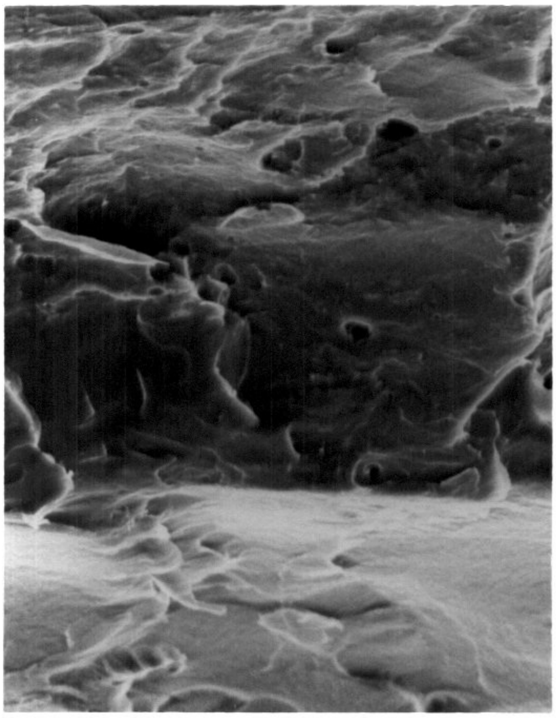


FIGURE 14

Photomicrograph of the Arnold acrylic resin processed by the Dry Heat-High Pressure Technique.

(1mm thick, 1000X, 10K V.)

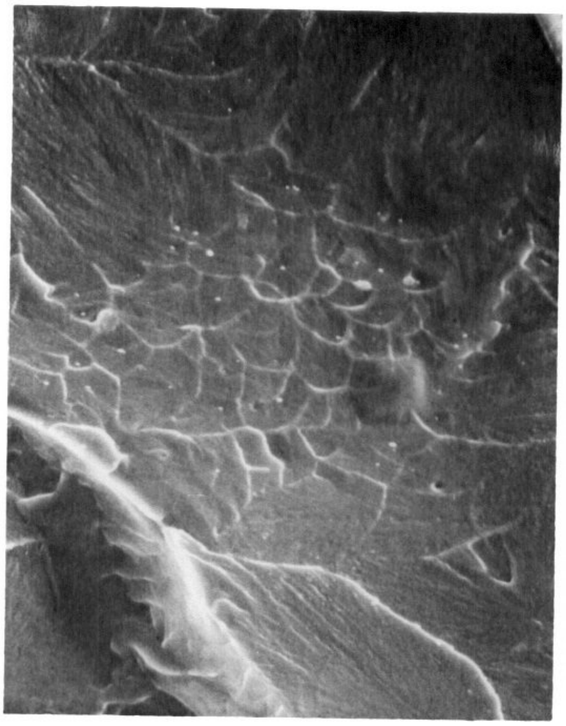


FIGURE 15

Photomicrograph of the Arnold acrylic resin processed by the Dry Heat-High Pressure Technique.

(2mm thick, 1000X, 10KV)

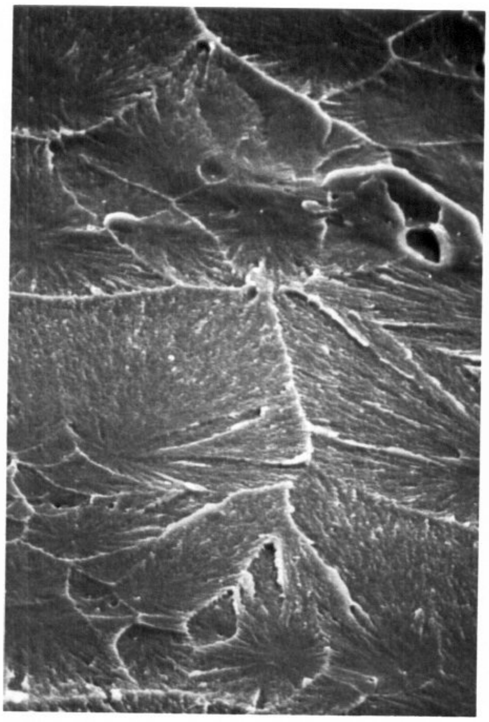


FIGURE 16

Photomicrograph of the Arnold acrylic resin processed by the Dry Heat-High Pressure Technique.

(3mm thick, 1000X, 10KV)

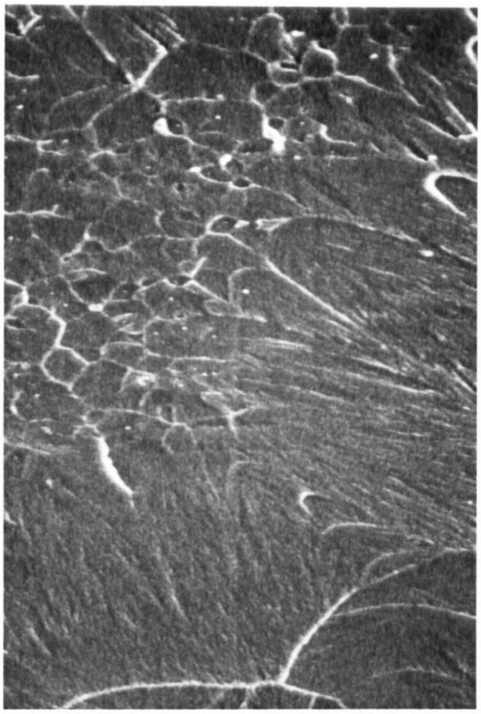


FIGURE 17

Photomicrograph of Duraflow acrylic resin processed by the Dry Heat-High Pressure Technique.

(1mm thick, 1000X, 10KV)

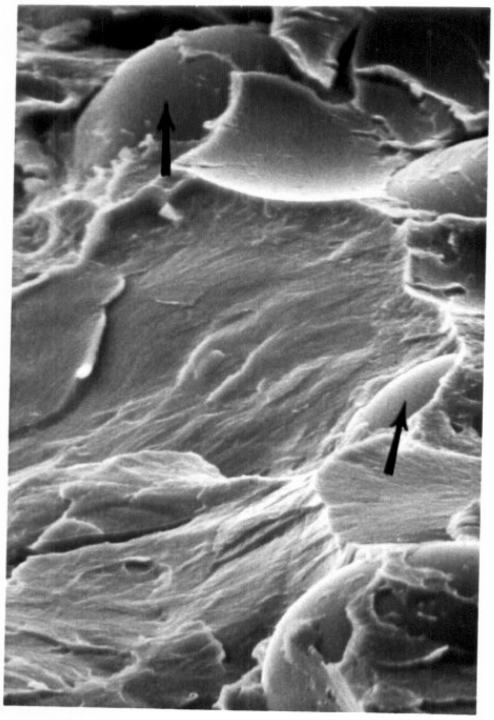


FIGURE 18

Photomicrograph of Duraflow acrylic resin processed by the Dry Heat-High Pressure Technique.

(2mm thick, 1000X, 10KV)

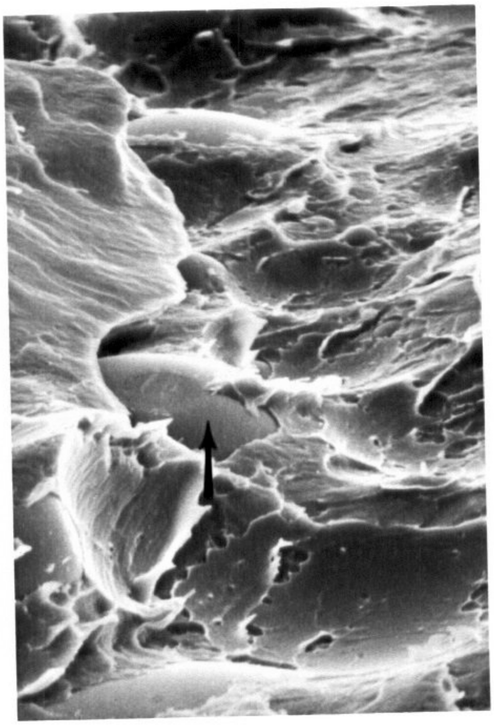


FIGURE 19

Photomicrograph of Duraflow acrylic resin processed by the Dry Heat-High Pressure Technique.
(3mm thick, 1000X, 10KV)

FIGURE 20

Photomicrograph of Leucitone acrylic resin processed by the Dry Heat-High Pressure Technique.

(1mm thick, 1000X, 10K V)

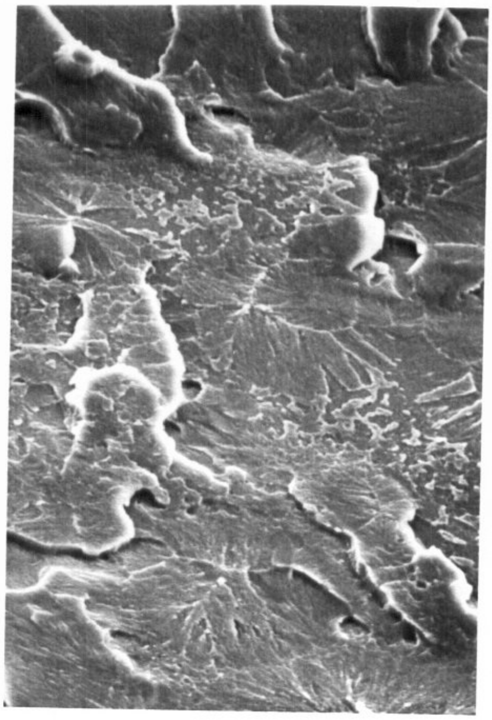


FIGURE 21

Photomicrograph of Leucitone acrylic resin processed by the Dry Heat-High Pressure Technique.

(2mm thick, 1000X, 10KV)

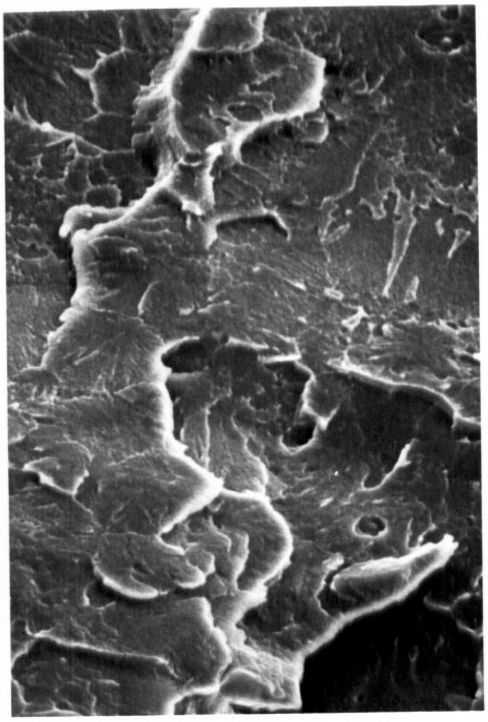


FIGURE 22

Photomicrograph of Leucitone acrylic resin processed by the Dry Heat-High Pressure Technique.
(3mm thick, 1000X, 15KV)

DISCUSSION

The proper fit of the denture in the mouth of a patient is of prime importance. Consequently, any change in the dimension of the denture base, either during processing or during function in the mouth, is of considerable importance and every effort should be made to prevent this from happening.

All acrylics suffer from the up-take of water. Therefore, all acrylics should be processed in a water atmosphere and always stored in a water bath while awaiting insertion. Acrylics which are processed by dry heat, are in a strange environment and, while they may appear hard and different than acrylics processed in a water atmosphere, they soon have the same characteristics of acrylics once they are inserted in the mouth since they are exposed to a wet environment.

Denture bases made of acrylic resin expand when immersed in water until equilibrium is reached. There is 1.5 to 2.0 percent sorption by weight. This amount of water will cause expansion of about 0.3% linearly and compensates for about one half of the curing shrinkage; although, other investigators (reference) have shown that water sorption compensates and, in other reports (references), more than compensates for the curing shrinkage.

Experiments with dentures have shown that the thick technique dentures expanded slightly more during 18 months of storage in water than did the thin technique dentures. This higher expansion, coupled with a low processing shrinkage, indicates that the thick technique dentures are consistently more stable in dimensions than the thin technique dentures. Therefore, the dentures should be made as thick as comfort and function will permit.

The results of this study show an overall percentage increase in weight ranging between 1.814% for Arnold, 1.673% for Duraflow, and 1.773% for Leucitone acrylic resin when processed by Compression Moulding technique. On the other hand, Arnold in the Dry Heat group showed an overall percentage increase in weight of 1.853% while Duraflow showed 1.667% and Leucitone 1.830%. The weight gain in the compression moulding technique was slightly less than the Dry Heat technique samples, but the standard deviation among all gains comparing the two techniques, was the same at 95% confidence level. It was also concluded that the sample variance increased along with sample thickness. The Duraflow showed generally lower weight gain than both Arnold and Leucitone in both processing techniques. On dehydration, examination of the data showed that the Compression Moulding technique had slightly greater weight loss than the Dry Heat technique, but the statistics indicate that the values were not significantly different.

In 1942, Osborne stated that the aim in polymerization of acrylics is to produce a denture free from any imperfections of color or structure. Since many of the failures in these materials are due to structural deficiencies in the form of the so called porosity, this phenomenon of "porosity" in acrylics is in no way analogous to that in vulcanite but is brought about by shrinkage of the monomer.

There has be observed a wide variation in different products in their tendency toward porosity, due to different ratios of powder and liquid. It is recommended, therefore, that as much powder be used with a given volume of liquid as is possible to incorporate. Caution should be expressed against the use of excess liquid in the mix if porosity is to be avoided (Peyton, 1951).

The justification for the low temperature practice for processing is based upon the critical polymerization temperature together with the exothermic heat liberated during the polymerizaiton process. It has been determined that methyl methacrylate polymerizes readily at a temperature of 158 to 167°F (70 to 75°C). At this temperature the exothermic heat of polymerization begins to be liberated and added to the external heat applied by the bath. If the external temperature is much above 167°F, the heat of polymerization is liberated rapidly to elevate the temperature sufficiently to cause porosity and internal stresses are likewise to be set up in the finished structure. Also, rapid shrinkage tends to occur in the structure that is cured at a high temperature. For these reasons, it is desirable that the temperature be kept low, in the range from 160° to 170°F, for most products. For purposes of safety, it is advised that this range be observed unless there is certainty that higher temperatures may be used without harmful effects.

In 1959, Atkinson and Dennis measured the pressure inside the acrylic resin during polymerization and concluded that, the higher the bath temperature, the higher the internal temperature and the higher the applied pressure necessary to prevent porosity. They also found that the maximum internal temperature was always considerably above that of the boiling point of the monomer.

The results of this study showed that both processing techniques produced porous free acrylic resin except for Leucitone 3mm thick processed by the Dry Heat, which showed gross porosity.

Although free monomer was not measured in any of the samples, this is not of primary importance. Smith and Bains, in 1971, showed that residual monomer leaches out within 24 hours when placed in a wet environment. Soaking in water overnight would leach out the free monomer from the prosthesis if any existed.

Various methods of curing dental resins, besides the conventional temperature controlled water bath, exists. In 1953, Sweeney reported the existence of more than 40 different processing techniques for curing of acrylic resin. However, it is doubtful that any one method is superior in producing a better denture. Each of these techniques, when well controlled, makes use of a more or less elaborate thermostatically controlled piece of equipment. It will be recognized, however, that the water bath offers the method of temperature control that is sometimes most convenient and accurate.

Most of the promotions for the newer methods of processing are aimed at replacing the constant temperature water bath of the open kettle types, with its unsightly appearance and steam vapour. Careful control of the time and temperature during processing by whatever method, is the most important factor to consider. Processing by the Dry Heat-High Pressure processing technique, however, is a time saver, as processing takes place in 15 minutes in contrast to the 9 hours overnight cure of the Compression Moulding Technique.

SUMMARY AND CONCLUSIONS

This investigation compared some of the properties of acrylic resin processed by the Dry Heat-High Pressure technique (Desnoyer's Press) versus the conventional Compression Moulding technique (Water Bath) using three different brands of Acrylic resins, namely, Arnold, Duraflow, and Leucitone acrylic resins.

Standard moulds of flat metal strips ranging in thickness between one and three millimeters were machined. These moulds were invested and the mould cavities created, were used to pack the acrylic resin dough according to the manufacturer's directions and then processed by either technique. The gain and loss of weight upon immersion in water or drying-out of different samples of acrylic resins over a four week period were recorded, tabulated and analyzed for statistical significance.

The results of this study showed no significant effect due to the processing technique on the weight change of the acrylic resin. On the other hand, some of the acrylic resin samples were fractured and examined under the scanning electron microscope for porosity. Almost all of the samples processed by either technique were free from porosity except for Leucitone acrylic resin, 3mm thick, processed by the Dry Heat-High Pressure technique. (The same observation was found by the company that promotes the dry heat machine with Leucitone acrylic resin.)

The conclusion drawn from this investigation was that the Dry Heat-High Pressure (Desnoyer's Press) is a cleaner, faster, and reliable way in processing and producing acrylic resin that is comparable to that produced by the conventional Compression Moulding technique. Such Dry Heat-High Pressure machine is a valuable addition to the dental laboratory equipment.

REFERENCES

1. Anderson, J. N.: Applied dental materials. Oxford, Blackwell Scientific Publications, 2nd ed., p. 236, 1961.
2. Atkinson, H. F. and Grant, A. A.: Exothermic reaction of polymethyl methacrylate. Aust. Dent. J., 1966.
3. Atkinson, H. F.: Details of a method of processing methyl methacrylate under air pressure. Aust. Dent. J., 58:74-79, 1954.
4. Atkinson, H. F. and Dennis, C. G.: Experiments on the polymerization of acrylic resin denture base material. Aust. Dent. J., 4:13, 1959.
5. Barrer, R. M. and Barrie: J. Bolym. Sci., 28:337-386, 1958.
6. Bates, J. F. and Smith, D. C.: Evaluation of indirect resilient liners for dentures; laboratory and clinical tests. J. Amer. Dent. Assoc., 70:344-353, 1965.
7. Bevan, E. M. and Earnshaw, R.: The role of water sorption in the solvent crazing of acrylic resins. Aust. Dent. J., 13:265, 1968.
8. Braden, M.: The absorption of water by acrylic resins and other materials. J. Prosthet. Dent., 14:307-316, 1964.
9. Brauer, G. M. and Sweeney, W. T.: Sorption of water by polymethyl methacrylate. Modern Plastic, 31:138, May, 1955.
10. Campbell, R. L.: Effects of water sorption on retention of acrylic resin denture bases. J. Amer. Dent. Assoc., 52:448, April, 1956.
11. Crank, J.: Mathematics of diffusion, ed. 2, pp. 276-289, 1957.
12. Hargreaves, A. S.: Equilibrium water uptake and denture base resin behavior. J. of Dentistry, 6:4,342-352, 1978.
13. Harman, I. M.: Effects of time and temperature on polymerization of a methyl methacrylate resin denture base. J. Amer. Dent. Assoc., 38:188, Feb., 1949.

14. Lowery, P. C.: The development of acrylic resin. D. Survey, 21:46-47, 1945.

15. Mewar, S. P.: Packing and processing acrylics. J. of all India Dent. Assoc., 28:7,105, 1955.

16. Milton Bell, A.: The acrylics. N. Y. Dent. Journal, 42:301-324, 1972.

17. Mirza, F. D.: Dimensional stability of acrylic resin dentures - clinical evaluation. J. Prosthet. Dent., 11:848, Sept.-Oct., 1961.

18. Mowery, W. E.: Dimensional stability of denture base resins. J. Amer. Dent. Assoc., 59:345, Sept., 1958.

19. Ohashi, M.: Observations of the generating mechanism of internal porosity in polymerizing of methyl methacrylate resin for dental use. J. Mihan. Univ. School of Dentistry, 4:1-13, 1961.

20. Osborne, J.: Investigations into the properties of acrylic resin denture bases. Brit. Dent. J., 9:7-30, 1942.

21. Paffenbarger, G. C., Woelfel, J. B. and Sweeney, W. T.: Dimensional changes in dentures. Dent. Pract., 13:64, Oct., 1962.

22. Peyton, F. A.: Packing and processing denture base resins. J. Amer. Dent. Assoc., 40:250-528, May, 1950.

23. Phillips, R.: Skinner's science of dental materials. 7th ed., pp. 199-203, 1973.

24. Pickett, H. G.: A comparison of six acrylic resin processing techniques. J. Amer. Dent. Assoc., 80:1309-1314, 1970.

25. Schoonover, I. C.: Factors affecting the physical and chemical properties and clinical behavior of dental resins. Int. Dent. J., 3, 1952.

26. Skinner, E. W. and Cooper, E. N.: Physical properties of denture resins in curing shrinkage and water sorption. J. Amer. Dent. Assoc., 30:1845, Dec., 1943.

27. Skinner, E. W.: Acrylic base materials, their physical properties. J. Prosthet. Dent., 1:161, Jan.-March, 1951.

28. Smith, D. C. and Bains, M. D. D.: The detection and estimation of the residual monomer in polymethyl methacrylate. J. Dent. Res., 35:16, 1971.

29. Sweeney, W. T.: Acrylic resins in prosthetic dentistry. Dent. Clin. North Am., pp. 593-602, (Index 1957-8), Nov., 1958.

30. Sweeney, W. T., Paffenbarger, G. C. and Beall, J. R.: Acrylic resins for dentures. J. Amer. Dent. Assoc., 29:7, Jan., 1942.

31. Takayama, Y.: An analysis of bubble contents in methyl methcacrylate resins. Unpublished paper (1952).

32. Tuckfield, W. J., Warner, H. K., and Guerin, B. D.: Acrylic resins in dentistry, Part II; their use for denture construction. Australia Dental Jouranl, 47:1,1-26, 1943.

33. The veronite work bench. Oct., 1946.

34. The veronite work bench. March, 1947.

35. Vieira, D. F.: A review of the dimensional changes which occur during processing and use of acrylic denture bases. Alum. Bull. Indiana Univ., School of Dent. So., 608, 1961.

36. Woefel, J. B., Paffenbarger, G. C., and Sweeney, W. T.: Change in dentures during storage in water and in service. J. Amer. Dent. Assoc., 62:643, June, 1961.

37. Woefel, J. B., Paffenbarger, G. C., and Sweeney, W. T.: Dimensional changes occurring in dentures during processing. J. Amer. Dent. Assoc., 61:413, Oct., 1960.

38. Woefel, J. B., Paffenbarger, G. C., and Sweeney, W. T.: Dimensional accuracy of dental base resins. J. Dent. Res., 238:752, July-Aug., 1959.