Elastic Impression Materials,
their Techniques
and Methods of Obtaining
Dies and Casts
in Crown and Bridgework.

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This critical review of literature concerning Elastic Impression Materials, their Techniques and Methods of obtaining Dies and Casts in Crown and Bridgework is submitted in support of candidature for the Degree of Master of Dental Surgery.

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27/12/61.
"Now dextrously her plumpers (she) draws,
That serve to fill her hollow jaws (cheeks),
Untwists a wire, and from her gums
A set of teeth completely comes."

- Jonathan Swift 1730.
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Introduction

Great accuracy has been obtained in the construction of inlays, crowns and bridges by the use of the direct method at the chairside. The fatigue and time consumed on the part of both the dentist and the patient, however, resulted in a search for a method which would enable equally accurate results to be obtained with the least amount of inconvenience to either the operator or the patient.

The advent of elastic impression materials has contributed much to Clinical Dentistry and has led to the development of various indirect techniques by which great, if not greater, accuracy may be obtained.

Impression procedures do not go as far back in History as the actual practice of Dentistry. Craftsmen amongst the ancient Phoenicians, Etruscans, Greeks and Romans made appliances for edentulous areas which used human teeth, carved bone or gold, copper and tin constructed on a "trial and error" basis. These appliances were kept in place by wire ligatures tied to the remaining teeth. Most of the ancient field of Dentistry was therefore of the fixed restorative type.

Philip Plaff, a German, in 1756 was the first to use plaster
models prepared from sectional wax impressions of the mouth (1), and it was 1840 before this method had been adopted in England. About this same time (1840-1850) the first type of copper electroformed die was constructed (2). In 1844 mouth impressions were taken in plaster. This was followed over a number of years by the introduction and use of other non elastic impression materials.

In 1925 a turning point was established when Alphons Poller (3) of Vienna obtained the first patent for a reversible hydrocolloid from the British Government. It was called Negocoll and it was supposed to be an impression material for moulding articles of all kinds, especially parts of living bodies. A similar material, under the name of Dentocoll, was later manufactured by the Detrey Brothers of Zurich and was introduced into the U.S.A by the L. D. Caulk Co. (4).

Paffenbarger (5) surveyed the work done and drew up specifications for a hydrocolloid impression material which are still used for impression material requirements for partial dentures. It remained for H. Spiro of Chicago in 1933, and A. W. Sears in 1937 to establish the value of hydrocolloid when they introduced a technique for its use in Crown and Bridgework (6).

Since Poller's introduction of the material Golden (7), Skinner and Kern (8), Knapp (9), Shapiro (10), Sterns (11), Kendrick (12) and Kimball (13) placed the material to the forefront and many others have added to their results.

World War II cut off the agar supplies and interest centred on an alginate impression material which had been first produced just before the War. This material has been developed to a point where it may be compared with the agar materials and can be used successfully in multiple inlay and bridge procedures (14). Among the first to advocate this material were Skinner and associates (15) (16).

Agar impression materials became available again at the end of the War and with the newly developed alginites the Dental Profession had two elastic impression materials for clinical use.

These two materials were not found to be completely satisfactory
at the time, and a synthetic rubber impression material was introduced in 1953 (17). This was the mercaptan rubber base material, the main constituent of which was discovered by Patrick in the U.S.A. in 1932 during research for a new antifreeze liquid (18). The silicone impression materials were also introduced at about the same time as the mercaptan rubber base materials.

Much research has gone into the development of these four elastic impression materials over the last five or six years. More research into elastic impression materials is to continue for there are yet problems to be solved and probably new materials and techniques to be developed.

This review discusses the four elastic impression materials used in Crown and Bridgework at the present time as well as the techniques that may be used with them and the various methods of producing dies and casts.
CHAPTER 1

Materials

Agar-Agar
Alginates

COLLOIDS - GENERAL CHARACTERISTICS.

Any solution in which the units of the solute are sufficiently large so that they will not dialyse through a suitable membrane is known as a colloid or colloidal sol. The units of the solute or dispersed phase may each be aggregations of molecules or a single large molecule. The particles are dispersed in the solvent or dispersion medium by virtue of the fact that they are repelled from each other by an inherent electric charge on each particle. The charge may be either positive or negative depending upon the particular colloid; – the particles in an agar-agar sol are negatively charged (19).

If the dispersed phase is of the same phase (solid, liquid or gas) as the dispersion medium the colloid is said to be an emulsion. If the dispersed phase and the dispersion medium are not of like phase the colloid is a suspension.

Since the colloidal state represents a highly dispersed system of fine particles of one phase in another it results that a characteristic property of the dispersed phase is to have an enormous surface area. This increase in surface area gives a corresponding increase in surface energy and surface reactions. A study of colloids (20) is, therefore, a study of small particles and the related surface effects
in the form of surface electrical charge or surface absorption. Not only is the surface energy important but also the interface between the two phases imparts important and characteristic properties to the system.

TYPICAL COLLOIDAL SYSTEMS.

Some colloidal systems are more important than others in Dentistry e.g. the distinction between a sol and a gel seems desirable since several of each find applications in dental operations. A sol resembles a solution in that it is made up of colloidal particles in a liquid. When a sol is chilled or caused to react to the addition of suitable chemicals it may be transformed to a gel. The dispersed colloidal particles increase in size by agglomeration and become entwined or entangled or otherwise develop a skeleton-like framework which holds the liquid phase within the network (20).

The liquid phase of either a sol or a gel is usually water but may be some organic liquid such as alcohol. Systems having water as one component are described as hydrosols or hydrogels. A more general term might be hydrocolloid, which is often used in Dentistry to describe the agar gels used as elastic impression materials. A general term to describe a system having an organic liquid as one component would be organosol or organogel.

PREPARATION OF COLLOIDS.

Two general methods are employed to form colloid particles (20) – a dispersion method in which massive particles are reduced by mechanical or natural processes to particles of colloidal dimensions, and a condensation method, in which molecular particles are agglomerated until they reach the colloidal range of size by chemical combination and precipitation or physical changes in the system.

Specific methods of formation include:

(i) Peptization, in which substances like agar, gelatin, organic gums, or resins are dispersed in a liquid phase to form a sol, either with or without the aid of heat.
(ii) Mechanical, which depend on high pressure grinding or shearing action, and are described as colloidal milling and homogenizing to disperse solid, liquid or gas phases as colloidal suspensions.

(iii) Attrition, which include various means of reduction of massive substances to particles of colloidal dimensions, often by mechanical grinding.

(iv) Precipitation, which include a variety of techniques and principles involving chemical reactions.

A hydrocolloid is by definition a colloid with water as the dispersion medium (15). The colloid may be a gel with a structure which allows the water to be held in the gel by capillary action. If the gel can be changed to a colloidal sol or a solution by some physical means such as heating, and if the gel is again formed upon cooling the hydrocolloid or gel is said to be reversible. On the other hand, if the colloidal sol is changed to a gel by chemical reaction for example, and the gel cannot be returned to the sol condition by simple means, the hydrocolloid is said to be irreversible.

The ultimate result with both types of hydrocolloid impression materials is the formation of a gel in the patient's mouth so that when the impression is removed all undercuts and dovetails will be accurately reproduced. The essential difference in these types of materials is the method by which the gel is formed in the patient's mouth (15).

PROCESS OF GELATION.

In the reversible type, the agar hydrocolloid is placed in boiling water, either in a tube as received or in a mixing syringe, and it is changed to a sol or liquid condition. While in this condition the material is placed in the tray, carried to the mouth and impressed against the parts to be reproduced. The sol is changed to a gel by the circulation of water through the tray before the impression is removed.

STRUCTURE OF THE GEL.

A gel consists of a network of minute, sub-microscopic fibrils
formed by the colloidal particles of the dispersed phase. The fibrils form a network of spaces or micelles in which the water is held by a adsorption. The fibrils of the reversible type of hydrocolloid are held together by the usual intermolecular forces or secondary valency bonds, but the molecules of the irreversible hydrocolloid are held together by bonds of the primary valency type (19).

This explains the difference of the alginate hydrocolloid. It cannot be reversed because the primary valency bonds are not disrupted by thermal agitation as are secondary valency bonds.

In the reversible type the chains are broken when the temperature is raised chiefly because of the increased agitation of the molecules. As the Kinetic Energy increases the micelles disunite and we have a sol (21) i.e. the forces of thermal agitation are greater than the forces of molecular attraction. When the temperature decreases the reverse takes place and the temperature at which rigidity is attained is the gelation temperature. The gel can decrease in temperature below this and may eventually become brittle.

IMbibITION AND SYNERESIS.

As the structure of a hydrocolloid consists of a great deal of water it is possible for the hydrocolloid to lose water from its surface by either evaporation or by exuding of fluid by a process known as syneresis. This exudate is not pure water, its composition depending on the composition of the hydrocolloid being used. This produces a shrinkage which results in an inaccuracy of the impression.

When the hydrocolloid is lacking in water, a water sorption will occur if placed in contact with water by a process called imbibition. This does not mean that when an impression is taken and syneresis is allowed, that if the impression is placed into water it will return to its original size. The more concentrated the gel the less it is subject to imbibition and syneresis.

The amount of syneresis can be controlled to a certain degree by the introduction of soluble salts into the gel, by the immersion of the gel in a solution with an osmotic pressure corresponding to that
of the dispersion medium (21) and to a certain extent by the humidity of the environment.

MEASUREMENT OF DIMENSIONAL CHANGE.

Dimensional change of an impression can be measured by different ways the most usual of which are the following: —

(i) A direct comparative measurement of the surface of an impression which gives the dimensional difference between two surfaces in the vertical direction at different points in the horizontal plane, as described by Rupp et al. (22).

(ii) By trying castings made from dies of the material used for the experiment and noting the degree of fit as used by James (23) and Phillips and Ito (24).

(iii) Use a tapered slot and bar die as used by Hollenback (25). This is a stainless steel block with a tapered slot extending across its upper surface, Fig. 1. The taper has been mathematically ground so that 0.001 longitudinal movement of the bar represents 0.0001 change in dimension laterally. When a test is made the bar is placed in the stone model secured from an impression of the block. If the dimension of the cast is correct the bar will be exactly flush with the end of the cast. If not the amount of protrusion or intrusion is measured with a small comparator and thus the results can be calculated.

(iv) Use of a mercury bath and sliding microscope as described by Hampson (26) or a Vernier Microscope with mercury bath as used in the Department of Prosthetic Dentistry, University of Sydney. Fig. 2.

AGAR–AGAR REVERSIBLE HYDROCOLLOIDS.

ORIGIN.

Agar–agar was originally the Malay name for certain East Indian red algae, but is now almost exclusively used in science to designate
Fig. 1.
Tapered Slot and Bar Die.
Fig. 2.

Vernier Microscope with Mercury Bath.

- Measurement of "Unrestrained" Dimensional Change.
Fig. 3.
Means of Measuring "Restained" Dimensional Change.
the dried gelatinous extract of certain species of red algae. Of the
50 or so varieties of red algae that will produce a hydrocolloid type
material only one is most suitable for dental impressions. This is
Gelidium cartilagineum (27).

Gelidium is found growing on rocks from tide level down to about
20 ft. under water, wherever the water is turbulent and foamy thereby
heavily airating the water. Gelidium needs plenty of exercise and
oxygen for its existence and is found only in temperate waters. It
is harvested by "skin diving" or by the aid of customary diving
equipment. It is cut or pulled from the rocks; pulling sets the growth
back, while cutting permits harvesting every three months.

The main locations for this weed are in the sea around Japan and
on the west coast of U.S.A. (27). It should be noted here that even
though it is the same species harvested the properties of the agar
hydrocolloid vary according to the place from which they are harvested.
In Japan the agar weed is piled up on the beach for drying and is
bleached slightly by sprinkling the drying weed with fresh water
routinely. The weed is then transported to the foothills of Mt.
Fujiyama and the juice extracted by boiling. The cooled gel is taken
up above the snow-line and allowed to freeze all winter. In the
Spring it is brought down, thawed out, dried and packed for shipment.
Freezing the agar gel separates about 90% of the water from the gel
and condences the agar. On remelting the liberated water runs off
carrying most of the impurities with it.

The American method of manufacture (27) is to freeze the gel
mechanically, break it up in very small pieces, thaw it out, drain
off the water, dry and pack it. Drying is accomplished by driving
hot air through the material and up a tall stack. As the lumps dry
out they become lighter. When dry enough to be carried up and out
of the stack the agar is ready to be packed. This type is known as
Flake Agar. Flake is ground to produce powdered agar. Japanese agar
is packed as strip, square and powdered.

The shorter freezing time given in U.S.A. is attributed by some
as causing the difference between the Japanese agar and the American
agar.
COMPOSITION AND STRUCTURE.

Apart from water which is the principle ingredient by weight, the main ingredient in a reversible impression material is agar-agar and is present in varying amounts from 5% - 15% by weight. This depends on the origin of the seaweed and to a small extent on the quality and quantity of other ingredients. The detailed formula is usually kept secret by the manufacturers. Other ingredients include borax to increase the strength of the gel, but as borax is a retarder for plaster and stone potassium sulphate is included to counteract this retarding action (14) (19). There are usually present also various other ingredients such as fillers, flavouring agents, rubber, wax etc. and various strengthening materials.

Mann (28) states that Kern suggested the following composition of a hydrocolloid as revealed by a patent application by Harrison.

<table>
<thead>
<tr>
<th>PARTS</th>
<th>AVERAGE(%)</th>
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<tbody>
<tr>
<td>An oleaginous material (e.g. vegetable, animal or mineral oil or fatty acid or a combination of these materials)</td>
<td>75-150</td>
</tr>
<tr>
<td>An emulsifying agent (e.g. triethanolamine soap)</td>
<td>3.6</td>
</tr>
<tr>
<td>A reversible gel-forming hydrocolloid (e.g. agar-agar)</td>
<td>25-175</td>
</tr>
<tr>
<td>Water</td>
<td>2000-2500</td>
</tr>
<tr>
<td>One or more thermoplastic substances selected from the group comprising waxes, balata-like substances, and resins or resinous gums (used as fillers and binders)</td>
<td>350-700</td>
</tr>
</tbody>
</table>

The patent further states that "the composition preferably also includes, as an additional ingredient, vulcanized rubber filaments 1-3% of the total of the above ingredients." In addition, "a small portion of scenting and flavoring constituents - a certain amount of
oil-soluble coloring material — and certain plaster—hardening agents such as tannic acid, burnt alum or copper sulphate may be incorporated in this mixture, if desired." Also "a strengthening or reinforcing material such as wool—flour, silk or cotton fibres, or other suitable material of desirable characteristics" may be added. It is interesting to note that Thompson reported substantially the same constituents in present—day hydrocolloids.

Morrant and Makinson (29) suggest a composition as the following; —

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distilled water</td>
<td>160mls</td>
</tr>
<tr>
<td>Thymol</td>
<td>.25gms</td>
</tr>
<tr>
<td>Potassium Sulphate</td>
<td>2.5gms</td>
</tr>
<tr>
<td>Glycerine</td>
<td>15.0gms</td>
</tr>
<tr>
<td>Kaolin</td>
<td>15.0gms</td>
</tr>
<tr>
<td>Agar—agar</td>
<td>20.0gms</td>
</tr>
</tbody>
</table>

This has been used in the Eastman Dental Hospital to make up the reversible impression material which they suggest be done in the following way: —

(i) The Potassium sulphate is dissolved in the distilled water without the application of heat. The powdered agar and thymol are added to this solution in the vessel and the contents allowed to stand for three hours to allow thorough saturation of the agar.

(ii) The bowl is then heated slowly and the mixture kept stirred the whole time with a large pestle until the temperature reaches 65.5°C. The bowl is then taken off the heat and the glycerine added and stirred in.

(iii) Heat is again applied until the temperature reaches 82°C when the Kaolin is added and stirred in.

(iv) The compound is then, while hot, put through a triple—roller ointment mill. This process produces a material in the form of friable flakes which is now packed in air—tight jars. This should take place in a round bottomed enamelled iron vessel
\frac{1}{2}" in thickness to avoid burning the agar in the heating stage. It should be able to contain \frac{1}{2}lb of colloid which is the amount produced by the quantities specified in the formula.

This composition and method of preparation is also used at the United Dental Hospital Sydney, in the Department of Prosthetic Dentistry of the University of Sydney to prepare reversible agar hydrocolloid for duplicating purposes.

Under the microscope agar-agar consists of a fine network resembling the parenchymatous cells of plants (26). The gels contain numerous biconvex lentiform cavities which are finer in stronger gels and larger in weaker gels. There seems to be a gradual change from the coarser to the finer structure as the concentration of agar increases. This means that we should not dilute the agar preparation to a great extent so as to facilitate ejection from the syringe, as it produces a weaker colloidal impression.

The exuded liquid of a gel during syneresis is not pure water but a dilute solution of the composition of which is determined by that of the original gel (26). Thus the composition of agar-agar can be changed and if reused over and over without proper care deficient working qualities may be produced.

CHEMISTRY.

Agar-agar is an organic colloid (polysaccharide). It is a sulphuric ester of a linear polymer of galactose. The generally accepted structural formula for agar-agar is the following (19):—
The material forms a colloidal sol with water which will liquify between 160°F and 212°F. The gelation temperature of agar-agar is about 99°F. These exact temperatures depend on several factors including the molecular weight and the purity of the agar.

PROPERTIES.

Agar-agar is almost colourless, tasteless and has no odour. The various additives produce the various colours and tastes for patient comfort.

1. Reversibility. — This is the ability of the gel to progress to a sol or liquid and return to its original gelatinous state. This would be of little value to us except that agar-agar in its reversibility demonstrates a classical example of hysteresis Fig. 5, i.e. the failure of either one of like phenomena to keep pace with the other (21).

![Fig. 5](image)

This means that there is a temperature lag between the sol point and the subsequent gel point which permits a reasonably wide temperature and time working range within tissue tolerance.

Agar-agar is subject to changes caused by syneresis and imbibition to a great degree and this is the main reason for dimensional change of impressions made from this colloid. This depends on the environment in which the impression is placed after removal from the mouth. The syneresis liquid of most agar hydrocolloids is acid in reaction (21).
This should be neutralized by a quick rinse of the impression in a base solution such as Bicarbonate of Soda followed by water and if a hydrocol accelerator is required a quick bath in a sulphate salt solution should follow. This acid so produced if not neutralized and allowed to remain in the impression will react with the hydrocol and produce an etched die or cast. The addition of certain salts such as NaCl, NaI, KBr, and KCl produces a syneresis liquid neutral to litmus.

If the material is allowed to regel and must be liquified a second or third time, longer boiling than the recommended ten minutes will be required (30). Reheating it eventually brings about a change in the material finally to a point that it will gel no longer (27).

2. Surface Reproducibility. — This is extremely good in agar hydrocolloids. If the surface of the object is not completely clean and dry i.e. if there is blood or saliva on a prepared tooth, this will be reproduced on the cast. Any irregularities or rough areas are readily seen in an abutment preparation. It is possible to see the margins of an excellent restoration on the cast by use of an eyeglass. The harder the stone with which the cast is poured the better is the surface detail and if the impression material is one which has in its composition a fixing chemical or if a fixing solution is used where necessary the reproducibility is much greater.

The properties necessary for accurate reproduction of cavity preparation include the following (30): —

(i) Sufficient fluidity or flow.
(ii) A gelation time which is adequate to permit injection into the preparation yet is not unduly prolonged.
(iii) Sufficient strength to resist fracture on removal from the mouth.
(iv) Minimum permanent deformation.
(v) Freedom from any deleterious effect on stone dies.

The agar hydrocolloids can meet all these requirements provided that the manufacturer’s instructions are observed.

3. Viscosity and Flow. — The degree of fluidity of the agar sol is influenced by: —

(i) Heat. The application of heat decreases the viscosity.

Boiling after the first fifteen minutes does not produce a
decrease of any practical importance in the viscosity.

(ii) Hydrogen Ion Concentration. At neutrality the agar sols present the maximum viscosity. A low pH produces low viscosity and also a high pH produces low viscosity (21).

(iii) Electrolytes. Even in low concentration electrolytes produce a sharp drop in the viscosity of agar sols. The degree of reduction of viscosity is in proportion to the increase in valency of the cationic electrolyte - the agar micellae carrying a weak negative charge (21). The effect of electrolytes on sol viscosity may be used to produce a material of optimum agar concentration to fulfill more adequately the considerations of elasticity and gel strength - particularly to a tooth cavity injection material in which a more fluid consistency is required and yet the reainment of gel strength is most desirable.

(iv) Agar Concentration. The greater the amount of solvent separating the molecules of the solution in thermal agitation, the more nearly we approach the fluidity of the solvent. At the same time a decrease in the concentration reduces the gel strength by thinning out the agar micelles to produce a weaker brush heap structure (21).

After the material has been liquified, it must be sufficiently viscous not to flow out of the tray, even though the tray is inverted when it is placed in the mouth. Its viscosity must be great enough that it will flow through the perforations in the tray to a slight extent without continuing to flow so that all the material runs out. On the other hand its viscosity must not be so great that it will not readily penetrate every detail of the soft tissues and teeth to be impressed. The agar sol by itself is likely to be too fluid for this purpose and the use of fillers and other modifiers is employed. The incorporation of borax definitely increases the viscosity of the sol (19).

4. Deformation and Elasticity. - In clinical use the impression material is required to pull around an undercut of a tooth or the mouth without rupturing and to return to its original shape as closely as possible. In addition the impression must have body and toughness so
that it will not deform or bend under the weight of the stone used to make the cast (14). The amount of recovery after deformation can be determined on a suitable test specimen e.g. a cylindrical specimen of the agar impression material of known length is compressed 12% of its length and held in this position for one min., after which the load is released. The length is then measured and any shortening is expressed as a % of the original length. This % value must not be more than 3%.

The stress-strain relationships of the agars are not linear over any portion of their stress-strain curve and although the slope of the curve is a general indication of its stiffness under static loading it is doubtful that true values for the modulus of elasticity and proportional limit can be computed (19). The greater the rate of loading of the specimen, the closer the stress-strain curve approaches a straight line. Repeated loading of the gel increases its stiffness. These facts mean that the impression should be deformed rapidly when it is removed from the mouth in order to preserve the original dimensions (24) i.e. a "snap" removal is used. —

Deformation can be brought about by relaxation of stresses produced (24). Such stresses can be brought about by the exertion of pressure on the tray during the gelation period.

Distortion during Gelation. The reversible hydrocolloids contract initially after gelation by syneresis. If the material is held rigidly by the retentions in the impression tray, such a contraction of the material may be manifested by an expansion of the space or area occupied by the impression. Owing to the elasticity of the gel, such an effect will be more pronounced the nearer the gel is to the tray (19).

The gelation begins adjacent to the cool tray and continues to the warmer mouth tissues. Since the sol is a poor thermal conductor, a rapid cooling may cause concentration of stress near the tray where the gelation first takes place. Consequently water at approx. 20°C is more suitable for cooling the impression than, for example, ice water (21) (24).

Van Rossem (27) states that the agars have a memory point which
permits them, especially when they are immersed in a solution of 2\% Potassium Sulphate, to return to their original size and thus a proper sized cast can result of impressions sent to the laboratory. In the light of other evidence (24) this procedure can only result in some inaccuracy and should not be followed. It is far safer to pour the cast immediately at the surgery.

5. Accuracy and Dimensional Stability. - As previously noted gels are subject to changes in dimension by syneresis and imbibition according to their environment. Once the impression is removed from the mouth and carried in air at room temperature syneresis usually starts immediately with a resulting shrinkage. Storage of the impression for any length of time is virtually impossible without some loss in accuracy. Storage in a relative humidity of 100\% does not prevent syneresis and inaccuracies of 0.1 - 0.3\% result (15).

Storage in a bath of some type may maintain an equilibrium condition and thus the accuracy, provided the osmotic pressure of the bath and the impression material are equal (21). Such a condition is not easy to realize practically, as variation in the delicately balanced osmotic pressure from one commercial material to another would be considerable or in some instances this variation is present in different batches of the same material.

James (23) states that the direction of change in dimensional accuracy depends on whether the impression material is locked to the tray or whether it is held loosely in the tray. If locked to the tray this means that there is a "plus" error due to a contraction of the impression material or an expansion of the impression space or vice versa. He also states that some agar hydrocolloids expand while others contract in the same medium. This was born out by Phillips and Ito (24) who used a Gaertner micrometer slide comparator microscope to study five different brands of hydrocolloid in various environments of air (35 - 50\% humidity), 100\% humidity, tap water, and 2\% potassium sulphate and concluded that 100\% humidity generally is safest for most reversible hydrocolloids. Other authors (31) (32) (33) (34) confirmed this.
Fig. 6.
Syneresis of an Agar-Agar Impression
Showing Resultant Shrinkage.
This suggests the conclusion that the best medium for storage to maintain greater accuracy may vary for each agar hydrocolloid or possibly from batch to batch of the same brand, and that some media react on different impression materials in opposite ways. The most accurate results are obtained when the cast is poured immediately (26) (31) (32) (35), or within 10 - 15 mins. (24) (36) (37). These were the results of tests made in conditions as similar as possible to those in the mouth.

If an impression is allowed to dehydrate, subsequent immersion in water before pouring does not produce an accurate die. One of the factors which makes it impossible to compensate for syneresis by immersion in water is that the dimensional change varies in different areas of the impression (32).

The relation of the impressed areas to their position in the tray is important. In general a large bulk of impression material between an undercut area is conductive to greater accuracy in the impression (36) provided the bulk itself does not produce an inaccuracy (35). The shelf life of an agar hydrocolloid is not an influencing factor in the accuracy of the impression provided that the material is kept under the proper conditions.

6. Effect of Electrolytes. - In the presence of electrolytes the three factors influencing the expansion of agar hydrocolloids are:
(i) The adsorption affinity of colloids towards ions both positive and negative.
(ii) The interaction of colloids and ions due to opposite electrical charges.
(iii) Competition for water between colloids and the outside ions surrounding the colloid particles.

Thus in the presence of electrolytes swelling is essentially the function of hydration of ions and electrokinetic potential (21).

7. Shrinkage. - Shrinkage of agar from the sol to the gel is in direct proportion to the temperature. The greatest amount of shrinkage occurs in the last area to gel or cool (5). Therefore:
(i) Impressions should be secured at the temperature point just
prior to gelation. In so doing the impression is obtained while the material is passing through the minimal volumetric change.

(ii) Since increased viscosity and final gel formation are due to an increase in formation of micelles as a result of lowered temperatures, shrinkage may continue, even after gelation. Therefore gelation temperatures below 70° – 80°F (21.1° – 26.6°C) should not be used (21). Fig. 7 shows the shrinkage of three hydrocolloids exposed to air over a period of 1 hr. and subsequent expansion when immersed in water (15).

(iii) Impressions should not be subjected to sudden chilling. The chilling agent passes through a tray surrounding the material on three sides and as said elsewhere; if cold water is introduced suddenly the central core around the teeth will be in the area of least cooling and greater shrinkage with consequent distortion (24) (35). Also the patient discomfort with the sudden introduction of ice water should be taken into consideration.

Thompson (37) states that the amount of shrinkage of hydrocolloid is rather constant and can be compensated for consistently if the hydrocol used is treated to expand 0.28%, i.e. Agar hydrocolloid is assumed to be shrinking 0.28%. It is very difficult, in the light of other evidence presented, to be able to have such a constant shrinkage percentage and to be able to compensate for it so accurately.

Fig. 7.
8. Compressive Strength. - According to the American Dental Specification No. 11 for Hydrocolloid Impression Material, the compressive strength of these materials should not be less than 2,000 gms./square cm. (28.4 lbs./sq.in.). This probably gives a measure of their resistance to rupture during removal from the area of which the impression is taken (19).

The inclusion of cotton fibres is used for strength and those hydrocolloids which contain fibres seem to be slightly more stable than those which do not.

9. Fixing Solutions. - These are used:

(i) To provide a storage medium for agar hydrocolloids so that deformation of the impression will not occur or is minimised. This is brought about by having a solution which is isotonic with agar so that syneresis and imbibition will not occur and the impression can be kept unpoured for a little time.

(ii) By reacting with the stone surface to (a) accelerate the setting time of the gypsum product, and overcome the retarding action of the gel surface on the setting of the dental stone; (b) react with the stone surface directly so as to increase its hardness.

The effectiveness of the solution in increasing the hardness of the stone surface appears to depend upon the chemical employed in the solution and its concentration in reference to the characteristics of the gel used for the impression. Examples of these chemicals employed are: - potassium sulphate, manganous sulphate, potash alum, and zinc sulphate. A recommended concentration is 2% (38). A 2% potassium sulphate solution was found best in that it would cause least change in the dimension of the impression (26).

It has been shown that the hardening solution itself may affect the dimensional stability of the hydrocolloid impression (24) (38). This effect also varies with the chemical employed, its concentration and the composition of the gel (21).

10. Effect on Stone Casts. - Reversible hydrocolloid will reproduce the sharpest of detail, but this accuracy can only be carried to the actual working die if the stone surface is smooth, dense and hard.
Fig. 8. Surface of Stone,
A. No $\text{K}_2\text{SO}_4$ Treatment of Impression.
B. $\text{K}_2\text{SO}_4$ Solution Used.
Agar inhibits the setting of dental stone. Borax when present in the impression material formula also inhibits the setting, and a cast will be produced which has a chalky, friable surface (14).

Potassium sulphate as an accelerator may overcome this tendency by being included in the impression material or by being used as a 2% fixing solution. Other ways of overcoming this effect on the stone are by copper plating the impression surface and reinforcing this with stone; by using a low water/powder ratio of stone and correct spatulation, remove excess fixing solution and water (without drying the impression surface completely as the stone will then stick to the agar) and to allow at least 30mins. and preferably one hour for the stone to set before removing it from the impression (33). However leaving the stone in the impression for too long a time has a deleterous effect also, because the exudate of the agar hydrocolloid may dissolve the water soluble salts in the stone and produce a rough or etched surface (39) (40).

The occasional imperfection on the surface of a die may be minimized by mixing the stone under vacuum and using a mixing gun in the preparation of the agar-agar.

SPECIFICATION. (14).

The agar material is required to be uniform and homogeneous, free from unpleasant odour or flavour and nonirritant to the tissues. It should impart a smooth surface to, and separate readily from, a hardened gypsum cast. Following a test inoculation, the impression material must remain free from mould growth, and any preservative added must be in quantities compatible with the use of the material in the mouth. When prepared as described by the manufacturer, the consistency must allow extrusion from a suitable syringe and permit adaptation to an impression tray. The material is required to take an impression of a certain test model without rupture. Gel formation or solidification must take place between mouth temperature and 45°C (113°F). The permanent deformation of the gel should be less than 3%, and the compressive strength of the gel when tested with a loading rate
of 400gm./sq.cm./mm. is required to be not less than 2000gm./sq.cm. (28.4 lb./sq.in.).

The Australian Standard Specification for Agar Impression material (41) is that:

(i) There should not be present poisonous ingredients in sufficient quantities to cause toxic reactions or irritate the oral tissues. The material should be of uniform texture and have a pleasant odour and flavour.

(ii) The material should become sufficiently plastic for impression procedures after 6 - 10 min. heating in boiling water. At temperatures within the range of 43° - 50°C the material should be sufficiently plastic for undercuts and fine anatomical details to be accurately reproduced, but it should not run out of a normal hydrocolloid metal impression tray. During manipulation the surface of the material should be smooth and the material should be free from lumps and granules and should show no evidence of separation of the constituents.

(iii) The gelation temperature should be between 36° and 43°C.

(iv) There should be a strain increase of between 4% and 10% under a 1250gm. weight when applied for 10 secs.

(v) The material should not rupture when subjected to a strain of 15% for 30 secs. (this strain being calculated on the original length of the specimen).

(vi) The compressive strength should not be less than 2500gm/sq.cm. when tested at a rate of 1000gm. per. min.

(vii) Provision for sampling should be made and each container should be correctly marked.

(viii) Correct information as to the procedure of manipulation of the material should be supplied by the manufacturer.

CRITICAL FACTORS OF MANIPULATION.

The agar latticework gel which is present in the hydrocolloid at room temperature must be broken down to produce a fluid sol which will accurately reproduce the cavity preparation. It has been
recognized that hydrocolloid has a different viscosity at various
temperature levels. At boiling point hydrocolloid is fluid; when
stored at lower temperatures it is semifluid; when cooled further for
the comfort of the patient during the taking of impressions, it
becomes more firm (42).

Immersion in boiling water for 8 - 12 mins. is a convenient
means of liquifying the material. The larger bulk of hydrocolloid
the longer it takes to liquify. There is no evidence that boiling for
longer than this period has a deleterious effect on the physical
properties (30). The material may be reused a second or third or
even fourth time (but not more), and an additional 2 - 4 mins. boiling
time should be allowed for each time it is reliquified.

Immediately after boiling the material may be stored by placing
the tube in water at 145° to 150°F and manipulating to ensure even
cooling. It may be kept thus for several hours. The filled tray is
tempered for a minimum of 2 min. at 115°F ± 2°F, a thin layer of
material which has been in direct contact with the water of the
tempering bath is removed and the material placed in the mouth. A
slightly more fluid agar material is used in injection syringes and
a similar procedure except that it is not necessary to temper the agar
before use. Convenient heaters can be obtained with three separate
compartments for boiling, storing and tempering.

To set the material in the mouth tap water is circulated through
the impression tray. At this temperature about 5 mins. is required
to gel the material. The higher the temperature of the cooling water
the longer will be the setting time of the gel. However if water
cooler than 55°F will gel the material too rapidly and will develop
internal stresses which will result in distortion of the impression.

ALGINATE IRREVERSIBLE HYDROCOLLOIDS.

The alginates have largely displaced agar hydrocolloids in
Prosthetic Dentistry and Orthodontics, but not so much in Crown and
Bridgework, although they can be used quite well in this part of
Dentistry. The appearance and working properties have changed over the years. Craddock (43) describes some of these changes. The method of packing; alginates were once supplied in single-unit, air tight packages and were probably sensitive to atmospheric oxidation and humidity. This doesn't seem to be the case now as materials come in large tins and can be used accurately till the last impression. The more recent products appear to be bulkier or "fluffier" than the older ones and require a smaller volume of water for saturation i.e. the strength and dimensional stability may be assumed to be greater. The older products either had a constant viscosity or appeared moist at first and gradually thickened while being spatulated, the newer materials appear dry initially and become more fluid as spatulation proceeds. The newer materials are not as "temperamental" as the older ones: variations in technique, temperature, W/P ratio etc. are not quite as important and fixing solutions have largely been done away with.

COMPOSITION AND CHEMISTRY.

The alginates are salts of alginic acid which is obtained from marine kelp (44). They change from the sol to the gel form by a chemical reaction which is irreversible. The sol form is always a double salt of alginic acid. The gel is an insoluble alginic acid salt. A typical formula of constituents for alginates is the following (14):

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage by wt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium alginate</td>
<td>15%</td>
</tr>
<tr>
<td>Calcium sulphate</td>
<td>8%</td>
</tr>
<tr>
<td>Sodium phosphate</td>
<td>2%</td>
</tr>
<tr>
<td>Modifiers (Zinc sulphate, fluorides, silicates, or borates)</td>
<td>5%</td>
</tr>
<tr>
<td>Filler (Diatomaceous earth)</td>
<td>70%</td>
</tr>
</tbody>
</table>

The alginic acid used is a linear polymer of anhydro-β-D-manuronic acid of high molecular weight (14). Its chemical structure
The potassium and sodium salts of alginic acid have properties which make them suitable for compounding a dental impression material. Solutions of these salts, when reacted upon by a calcium salt, produce an elastic gel. The potassium alginate and the calcium sulphate reaction is modified by the sodium phosphate which slows the setting time. As the sparingly soluble Calcium sulphate dissolves, it reacts with the sodium phosphate, and only when all of the latter is reacted does the calcium sulphate become available for reaction with the potassium alginate. This then produces the irreversible calcium alginate gel and potassium sulphate. If there is no sodium phosphate present the gel sets too quickly for use as an impression material (46).

By varying the quantity of sodium phosphate therefore, the manufacturer can control the setting time of the impression material. The diatomaceous earth is a filler which gives body and consistency to the mixed impression material. The other ingredients are to increase the strength and to improve the surface quality of the stone cast. The chemical equations are as follows (45): -

\[ 2\text{Na}_3\text{P}_4\text{O}_{10} + 3\text{CaSO}_4 \rightarrow \text{Ca}_3(\text{PO}_4)_2 + 3\text{Na}_2\text{SO}_4 \] \hspace{1cm} (I)

\[ \text{K}_2\text{Alg} + \frac{3}{2}\text{CaSO}_4 \rightarrow \frac{3}{2}\text{K}_2\text{SO}_4 + \text{Ca}_2\text{Alg} \] \hspace{1cm} (II)
The final structure of the gel is possibly an immediate brush-heap network composed of partially cross-linked molecules of calcium alginate. The unreacted alginate sol, excess water, and particles of filler can be pictured as being entangled in such a network to produce a gel structure of a type which can be used for the obtaining of impressions.

PROPERTIES.
1. Reversibility and Reproduction. — The alginates are not reversible. Their surface reproduction ability approaches that of the agar hydrocolloids. The same precautions apply with this material as with the agar, in that if present, all blood, saliva, debris etc. will be reproduced. There may be a slightly greater tendency to entrap air bubbles with the alginates. These air bubbles may be formed either during spatulation and are usually small or during seating of the impression in which case they are larger.

Hosoda and Fusayama (47) studied the surface reproduction of detail using lines 8μ to 40μ in width inscribed on a brass plate as original model. The alginate was poured immediately after an immediate fixing — the excess fixing solution being gently shaken off and the poured impression kept at 100% humidity. A microscope which magnified 40 times and an oblique illumination was used to examine the reproduced lines and surfaces of the stone models.

The 10 micron line could be reproduced by fixing impressions in a 0.5 to 2.0% Zinc Sulphate solution for 30 – 60 secs. when poured with a hydrocal stone. Increasing the fixing time roughened the model surface. The 30 micron line was the finest produced without fixing. The 8 micron line could not be reproduced.

2. The Strength of Alginates. — The strength of alginates is adequate if they are correctly manipulated. This requires spatulation for the correct time, the use of the manufacturer's recommended W/P ratio, and retention in the mouth for 2 mins. after the loss of surface tackiness. The composition of an alginate can readily affect its gel strength. The type of reactor used can affect the strength.
considerably. The type and amount of the soluble alginate used is of considerable importance, as well as the nature of the other ingredients, and their proportions (45).

Although the alginate materials have higher compressive strength values than the agar type, they tear more readily in thin sections than do agar hydrocolloids. This is noticed when the alginates are used in taking impressions of inlay preparations. The strength of the alginate gel increases for several minutes after the initial gelation.

3. Viscosity and Elasticity. — These properties are necessary in alginates as with agar hydrocolloids in that the impression material must flow into the undercut areas but must have sufficient viscosity not to "fall out" of the tray. It must be able to flow through the retentive holes of the tray. The soluble alginates dissolve in water and they form viscous sols at relatively low concentrations. The viscosity of the sol for a given concentration increases with the molecular weight of the alginate.

Anderson (48) states that during manipulation and when testing alginates three physical states are recognised.

(i) Plastic
(ii) Neither plastic nor elastic
(iii) Elastic

The accurate determination of the end of (i) and the beginning of (iii) is important as any change of shape during (ii), either by manipulation or by removal of the impression from the mouth will produce permanent deformation.

It was found that with the alginates cessation of flow also indicated the beginning of "elastic memory" i.e. the end of the period of accurate manipulation. The alginates are elastic enough for clinical use even though they have a tendency to tear or rupture more readily than the agars. They recover well following compression or bending and will satisfy the requirement of 3% permanent deformation after subjection to a 12% strain for 1 min.

4. Accuracy, Dimensional Stability. — Skinner (45) states that the dimensional changes occurring with the alginate gels is characterized
by a slight initial expansion. The expansion can probably be attributed to a continued imbibition of the residual free water by the gel after the initial gelation. Also that some of the alginates apparently do not lose water by evaporation as readily as do the reversible agars, since their contraction in air is not as great and that storage in water is not indicated for alginate impressions.

The dimensional stability is also influenced by the formation of the insoluble alginate being accompanied by a contraction. If the second reaction on page 25 is prolonged, the gel may continue to contract even though it may be immersed in water. As with agar hydrocolloids, the alginates are kept with least distortion at 100% humidity and the cast should be poured as soon as possible. They may be stored for very short periods by being wrapped in a wet towel. In general the alginates are more sensitive to environmental changes.

Skinner and Pomes (16) and Skinner and Hoblit (36) record that impressions obtained with alginates compare well in accuracy to those obtained with agar-agar, but the Commonwealth Bureau of Dental Standards (49) states that agar hydrocolloids have an 85 - 90% recoverage whereas alginates have only a 50 - 70% recoverage.

Inaccuracies with alginates may be the result of allowing the ingredients of the powder, which have different specific gravities, to settle out and therefore not getting the correct percentage of ingredients with each mix — particularly so if a large can is used.

It has been reported that the inaccuracies of alginates were related to the sub-microscopic pulling away of the material from the tray and that hot sticky wax used as a retainer in the tray produced a very accurate impression (50). More work is being carried out on this point.

5. Storage Media and Surface Qualities of Stone Dies. — Morrant and Elphicke (51) studied the behaviour of a brand of alginate in air, water, under a damp cloth, in alum fixing solution, 100% humidity, motor oil and liquid paraffin B.P. Liquid paraffin B.P. was found to be the most satisfactory of these media for storage purposes, and no significant difference was noticed between castings made from
impressions stored in liquid paraffin B.P. for 48 hours and those poured immediately.

Most authors (15) (26) (30) (38) (44), however, agree that, as with agar hydrocolloids, alginites should be poured immediately and that failure to use a fixing solution if recommended resulted in a chalky or soft stone surface (52) (53). The least change occurred in an atmosphere of 100% humidity (38) (54). It is interesting to note that the use of fixing solutions tends to stabilize the impression in any storage medium.

Dies made from impressions decreased in accuracy according to the length of time stored. The longer the storage the greater the distortion. As with agar hydrocolloids when an alginate, previously left out of any storage medium, was placed in water the impression took up water but did not return to its original shape.

Hosoda and Fusayama (47) concluded that an alginate impression for indirect inlay and crown work should be fixed even if the manufacturer directed no fixing and that fixing in a 1% zinc sulphate solution for 30 secs. produced the most excellent surface for any brand of alginate tested. Impressions must not be left for too long a time in fixing solutions as distortion occurs, neither should the concentration of the fixing solution be too strong; 5% potassium sulphate solutions used for storing impressions may result in stone dies having a surface roughness due, probably, to the chemical action of the potassium sulphate on the impression material thus destroying the surface of the cast. Any excess water should also be removed before pouring the die as this is incorporated in the surface of the die and weakens it.

SPECIFICATION.
The alginate powder should be of fine texture, uniform and free from foreign materials, and, when mixed with water in the recommended proportions, it should give a smooth plastic mass suitable for taking an impression in the oral cavity. Odour and flavour should be acceptable and no irritant substances should be present. The mixing
time should not exceed 1 min. and the working time should not be less than 2 min. when measured from the beginning of the mix.

The mixed paste should register fine detail satisfactorily and the impression must be compatible with gypsum model materials and separate cleanly from a cast. The strength of a standard specimen of the set alginate should be not less than 50 lb./sq.in. The elastic recovery of an impression as measured on a test cylinder of the set material should result in a permanent deformation of not more than 3% after a 12% compression for 1 min. The shelf life of the alginate may be tested by storage of the package for a week at 60°C and 100% R.H., at the end of which period a test cylinder of the material should retain 75% of the original strength.

The above specification has been proposed by the Committee of the Dental Materials Group of the International Association for Dental Research (14).

The Australian Standards Specification for Alginates (55) is much the same as that for Agar where applicable, the differences being:

(i) The setting time of the material should be not less than 2 1/2 min. nor more than 5 min.
(ii) The increased strain in compression should be between 5 and 15%.
(iii) The compressive strength should not be less than 5,000 gm./sq.cm. when tested at a rate of 1,000 gm./mm.
(iv) The material when stored in the original container should retain its properties for at least one year.

MANIPULATION OF ALGINATES.

Agar hydrocolloids are mostly manipulated by mechanical means whereas alginites depend on human variation to a greater degree. This means that alginites are more susceptible to variations in time, temperature, W/P ratio, mixing, etc., and thus there are more sources for error with this impression material, but good results can be obtained if the manufacturer's directions are followed closely. Since one brand of alginate is not entirely similar to the next, this is
important.

The measuring containers provided should be used as changes in the W/F ratio will alter the consistency and setting times of the mixed material and also the strength and quality of the impression. The mixing bowl and spatula should be clean and dry. Sometimes it is necessary to chill these so as to keep the manipulation time as long as possible; particularly in summer time or in the tropics. If a large can of alginate powder is used the contents should be shaken before measuring out the required amount so as to keep the ingredients well mixed. If this is not done variation in setting time and strength will be noticed. Also the surface of the stone die or cast may be affected. The lid of the can must be tightly sealed between uses of the material and stored in a dry place; when mixing, care should be taken that particles of partially mixed alginate or water are not splashed into the can if this has been left open. If impressions are taken only occasionally it may be better to use the powder from individual metal foil units.

The temperatures of the mixing water should be 70° F or less (16) (44) (54). This avoids premature setting of the alginate and care must be taken in hot weather that the temperature of tap water is not above 70° F.

The effect of the spatulation time on the gelation time of a typical alginate is not of importance (16), but it has an effect on the strength of the set impression. Insufficient spatulation results in failure of the ingredients to dissolve sufficiently. Overspatulation gives equally poor results since any calcium alginate gel formed during prolonged spatulation will be broken up and the strength will be impaired. The spatulation time, about 1 min., should be noted with a timepiece and not just estimated by the appearance of the mix (16). Even after thorough spatulation the smoothness of the final mix will differ in various brands of alginate.

After the first 15 - 20 strokes, during which time the powder is incorporated into the water, the rate of mixing should be about 200 revolutions per minute (16) (30) (32) (54). The material should be mixed well against the sides of the bowl, not just stirred.
If using a syringe technique it is necessary to lengthen the working time and to thin the mixture sufficiently for ejecting easily and evenly through the needle. To do this ice water may be used (32) (54) (56), and the W/P ratio increased usually by 4 - ccs. (30) (54). The material can then be drawn up into the syringe easily and without undue haste.

When the alginate is placed in a tray - the tray having been previously properly adapted, with stops and extensions added etc. - it should be pushed well down into the retentive holes of the tray so that large air bubbles, which may have been introduced, are removed. The tray is filled properly and a finger may be used to pat the alginate down. This finger should not be wet as this introduces extra water to the part of the impression in which greatest accuracy of surface reproduction and strength are required, and while the outside areas of alginate have set the inner more fluid part has not, and inaccuracies may result.
COMMON CAUSES OF FAILURE OF HYDROCOLLOIDS.

**Rough or Chalky Surface on Cast.**

<table>
<thead>
<tr>
<th>Agar</th>
<th>Alginate</th>
</tr>
</thead>
<tbody>
<tr>
<td>No K₂SO₄ treatment of</td>
<td>No fixing solution used when required.</td>
</tr>
<tr>
<td>impression.</td>
<td>(a) Improper W/P ratio for stone.</td>
</tr>
<tr>
<td></td>
<td>(b) Removal of cast or die from impression before 30 mins.</td>
</tr>
<tr>
<td></td>
<td>(c) Excess water or fixing solution not blown from impression.</td>
</tr>
<tr>
<td></td>
<td>(d) Too much vibration during pouring of stone.</td>
</tr>
</tbody>
</table>

**Inaccuracy.**

<table>
<thead>
<tr>
<th>Agar</th>
<th>Alginate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Chilling with ice water</td>
<td>1. Leaving impression in mouth too long.</td>
</tr>
<tr>
<td>2. Re-use of too old material.</td>
<td></td>
</tr>
<tr>
<td>(a) Teasing impression out.</td>
<td>(b) Storage of impression before pouring.</td>
</tr>
<tr>
<td>(c) Movement of tray during gelation.</td>
<td></td>
</tr>
<tr>
<td>(d) Removal from mouth too soon.</td>
<td></td>
</tr>
</tbody>
</table>

**Material Stiff or Grainy.**

<table>
<thead>
<tr>
<th>Agar</th>
<th>Alginate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Insufficient boiling.</td>
<td>1. Insufficient spatulation.</td>
</tr>
<tr>
<td>2. Storage temperature too low.</td>
<td>2. Water too warm.</td>
</tr>
<tr>
<td>3. Prolonged storage or tempering.</td>
<td>3. Insufficient water.</td>
</tr>
<tr>
<td>4. Tube not immersed completely during preparation.</td>
<td></td>
</tr>
</tbody>
</table>

**Fracture.**

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Teasing impression out of mouth.</td>
</tr>
<tr>
<td>3. Insufficient gelation.</td>
</tr>
</tbody>
</table>
Chapter 11

Materials

Thiokols
Silicones

The mercaptan polysulphide and silicone rubbers are essentially liquid polymers which can be converted to semisolid rubbers at room temperature by being mixed with a suitable catalyst and used as an impression material. To facilitate this use as an impression material the liquid polymer is mixed with fillers to form a convenient paste. These materials, although they are relatively new, are sufficiently accurate clinically to enable the construction of fixed prosthesis, inlays and dentures of a highly precisional nature. Improvements are being made day by day, and objectionable properties such as the colour and odour of the mercaptans, and the poor dimensional qualities of the silicones are being removed.

Mercaptan Base Materials or Thiokols.

The development of the Thiokol polysulphide liquid polymers for industrial use has been described by Fettes and Jorczak (57) (58).
These materials have been modified and adapted for dental use. The impression material is supplied in two collapsable tubes one containing a white paste in which the polymer and fillers are contained, and the other a brown paste which contains the catalyst and a suitable vehicle.

COMPOSITION AND CHEMISTRY.

The rubbers as developed for industrial use are clear, amber liquids produced in a range of viscosities. LP 2, the form of rubber used in dental impression materials, is a brownish, syrupy liquid with a molecular weight of about 4,000. When heated it becomes thinner. The viscosity is, for example 44,000 cp at 25°C., and 22,000 cp at 37°C. (59).

The probable structural formula is the following (14) (60): -

$$\text{R} - \text{S} - \text{S} - \text{R}_3$$

where R is assumed to be: $$\text{C}_2\text{H}_4 - 0 - \text{C}_3\text{H}_6 - 0 - \text{C}_7\text{H}_4$$

These polymers when oxidized produce rubbers. Most of the oxidizing agents require from several hours to several days to effect a complete cure. Lead peroxide is used as an oxidizing agent in dental impression compounds, and the curing may be represented as follows (14):

$$2 \text{HS} - (\text{R} - \text{S} - \text{S})_3 \rightarrow \text{R} - \text{SH} + \text{PbO}_2 \rightarrow$$

$$-\text{S} (\text{R} - \text{S} - \text{S})_3 - \text{S} - \text{R} - \text{Pb} - \text{S} - \text{R(S - S - R)}_3 - \text{S} - + 2\text{H}_2\text{O}$$

The addition of sulphur is believed to complete the reaction as follows:

$$-\text{S} (\text{R} - \text{S} - \text{S})_3 - \text{R} - \text{S} - \text{Pb} - \text{S} - \text{R(S - S - R)}_3 - \text{S} - + \text{S} \rightarrow$$

$$-\text{S} (\text{R} - \text{S} - \text{S})_3 - \text{R} - \text{S} - \text{S} - \text{R(S - S - R)}_3 - \text{S} - + \text{PbS}$$

The liquid polymers are compounded with inert fillers to modify
the viscosity and to give strength and colour to the set impression. Zinc oxide and calcium sulphate are two materials which have been used for this purpose. The lead peroxide catalyst is compounded with sulphur and an oil to produce a paste convenient for clinical use.

On reaction of LP 2 with PbO₂ the molecular size is increased at the same time as the viscosity becomes higher. The reaction is an exothermic one. If a sufficient amount of lead peroxide is present the mix is converted into a rather soft rubber compound. The usual ratio is 8 parts PbO₂ to 100 parts LP 2; lower proportions of PbO₂ result in incomplete polymerization (59).

The rate of reaction between LP 2 and PbO₂ can be controlled by the following:

(i) The smaller the particle size of the lead peroxide the faster and more complete the polymerization.

(ii) The rate of reaction is approximately doubled with every temperature rise of 10° C., at least within the range 20° - 70° C. (59).

(iii) The higher the humidity the quicker the reaction; one drop of water accelerates the set tremendously.

(iv) Stearic and oleic acid in small amounts (1 - 3%) retarded the cure considerably.

The polysulphide possesses extremely reactive sulphur hydrogen terminals in its chain construction, and a polymerization or cold vulcanization can thus be brought about to produce an elastic, strong and dimensionally stable synthetic rubber (61).

Pearson (60) provides the following analysis of a mercaptan rubber:

<table>
<thead>
<tr>
<th>Base</th>
<th>Accelerator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polysulphide rubber</td>
<td>Lead peroxide</td>
</tr>
<tr>
<td>Zinc oxide</td>
<td>Sulphur</td>
</tr>
<tr>
<td>Calcium sulphate</td>
<td>Castor oil</td>
</tr>
<tr>
<td></td>
<td>Other substances</td>
</tr>
<tr>
<td>79.72%</td>
<td>77.65%</td>
</tr>
<tr>
<td>4.89%</td>
<td>3.52%</td>
</tr>
<tr>
<td>15.39%</td>
<td>16.84%</td>
</tr>
</tbody>
</table>

The sulphur may also help speed the cure. Pearson (60) also
studied the possible dangers of introducing a material with such a high lead content into the oral cavity, by an incubation procedure over a week and found that not even small traces of lead were present in the saliva; and assumed that no harm can eventuate, particularly during the short period in which the impression materials remain in the mouth.

The Thiokols used commercially are cured under pressure and heat (62). To prepare a Thiokol which will polymerize at room temperature (57) (58), a mass of polymerized alkyl sulphide is obtained from a suspension of an alkyl halide or sodium sulphide. If the alkyl sulphide so produced is then treated with sodium hydrogen sulphide and sodium sulphite, a compound with thio- end groups, i.e. SH can be obtained. The molecular weight or chain length will depend on the processing conditions. This partially depolymerized polysulphide is a thio-alcohol in which SH substitutes for OH; hence the name Thiokol. Many Thiokols are possible. Because the thio- end-groups tend to break down in the presence of oxidizing agents or substances producing free radicles, condensation polymerization may be initiated by addition of suitable chemicals.

In such reactions long chain molecules are produced. The presence of 2% trichlorpropane aids cross-linking between the chains. The final structure of the polymer determines its physical properties. The chains are probably kinked or coiled like springs, and intermolecular attraction is exerted not only between adjacent molecules but also between adjacent portions of the same molecule.

The occasional cross-linking between chains reinforces molecular binding, but does not confer absolute rigidity upon the solids.

PROPERTIES.

Polysulphide rubbers are irreversible and have an unpleasant smell and taste. During polymerization they are sticky to the fingers and to clothing and will stain linen. They are of brown colour due to the lead peroxide in their makeup. Phillips (63) mentions one product which doesn't have this brown colour and probably doesn't have
lead peroxide as an ingredient. They are extremely solvent resistant and can withstand temperatures over the range of $-70^\circ$ to $300^\circ$ F.

Chemically a Thiokol lies somewhere between a resin and a synthetic rubber. Unlike natural rubber, it has a high resistance to decomposition by petrol and oil, consequently it has been used in the motor industry for years for petrol lines and hydraulic brake tubes. It is neutral to the action of water, sunlight and oxygen (18).

1. Surface Detail and Reproduction. — The Thiokols are excellent in this capacity to reproduce minute surface detail, so much so that this ability exceeded the reproduction capacities of the gypsum model materials (63) (64) and appears superior to other types of impression materials. This is supported by Hosoda and Fusayama (47) who report that the mercaptan rubber base impressions reproduced a $10/\mu$ line with any type of stone but failed to reproduce the $8/\mu$ line, although it was reproduced on the impression surface.

Using this material an impression was taken in a brass ring of a steel die resembling an M.O.D. inlay preparation. The impression was copper plated and a die poured in fusible alloy and the ring and impression removed. A gold casting made from this copper plated model was transferred to the original steel die and found to fit equally well (60).

2. Strength. — The tensile strength, tear strength and compressive strength of most of the Thiokol materials, particularly the "regular type" and the "heavy type" are comparatively high (65). In fact it is virtually impossible to compress many of them sufficiently to cause a fracture. Consequently there is little danger of a fracture occurring during the removal of an impression made with a rubber material. Unfortunately such strength is not necessarily an advantage, since it may give the operator a false sense of security (65). The impression may be considerably distorted during its removal and yet appear to be normal so far as evidence of fracture damage is concerned. From this viewpoint an impression material which will fracture near its elastic limit is to be preferred.

The compressive strengths of the rubber were all greater than
3000 g/cm. in a test conducted by Hampson (66) which far exceeded the
agars. Hampson also showed that the amount of deformation the
materials can withstand is not dependant on high compressive strength.

3. Setting Times. - This property is important to both dentist and
patient and, therefore, there should be a good correlation between
setting time and the manipulation time. There must be sufficient
working time to permit mixing, injection if necessary, and seating of
the tray. Polymerization should take place rapidly enough to prevent
any distortion while the tray is in position and to minimize the time
required for holding the tray in the mouth.

The manipulation and final set times can be determined fairly
accurately by using a penetrometer with a needle and weight selected
to suit these materials. The Vicat penetrometer with a 3mm. diameter
needle and a total weight of 300gms. has been used for these
determinations. A metal ring, 8mm. high and 16mm. in diameter, is
filled with freshly mixed material and placed on the penetrometer base.
The needle is applied to the surface of the rubber for 10secs. and a
reading taken. This is repeated every 30 secs. The initial set
(manipulation time) is that time at which the needle no longer
completely penetrates the specimen to the bottom of the ring. The final
set is taken as the time of the first of three identical penetration
readings. When the material has set, the elasticity will still allow
penetration of the needle, but it is the same at each application.

Skinner and Cooper (67) found that the manipulation times of
the materials tested in their survey varied between 3.0 and 9.0 mins.
and the setting times varied between 5 and 12.5 mins. when both
properties were measured at 25°C (77°F). At 37°C (99°F) the two
properties varied between 2 and 4 mins. and 3 and 7.5 mins. respectively.

The twelve products tested by Myers et al (68) showed
variations in manipulation time from 1.5 mins. to 11 mins., and in
setting time from 2.5 min. to 17.0 min. at room temperature. The
setting of the slow-setting products was speeded by contact with the
fast setting products.

Temperature and humidity will influence the setting time (65)
The higher the temperature and the greater the humidity the more rapid the set, particularly of the slower setting products. The base/accelerator ratio also affects the setting time but other properties are affected also and this system should not be used to alter the setting time. It is essential that the material is adequately cured before removal; the minimum time for the positional tray to be held in the mouth is 8 min. i.e. approximately 10 min. from the start of mix (63).

The lack of surface tackiness is not a satisfactory indicator of the setting time (65) (69). The setting time of Thiokols should be determined as that time at which the optimal elastic properties are obtained. Possibly the best method for clinical use is to prod the material with a blunt instrument. When no perceptible indentation or deformation is obtained, it can be concluded that the material has set. 4. Elasticity. - The elasticity of this material is quite dramatic in that it could not be crushed under compression. The Thiokol merely flattened out and sprang back into place when the load was released (67). Skinner and Cooper (67) also tested the strain and set values of these materials after hardening for 30 mins. at room temperature and also 3 mins. after setting. When tested after 30 min. of hardening the strain and set values of all the materials tested were within the range of the American Dental Association specification for Hydrocolloids. Fig. 10. When tested 3 min. after set the values of the percentage set of some materials were higher than the specification limit.

Myers et al (68) tested nine Thiokol products 10 min. after commencement of mixing, this being the time at which the impression would usually be removed from the mouth. It was found that all the products fell within the limits set for the percentage strain. The lower the amount of permanent set values shown, the more satisfactory is the material because the smaller is the amount of permanent deformation when the material is drawn over undercuts. The values of set vary with different amounts of strain and to obtain a true picture of the behaviour of these materials it is essential to estimate the
set over a wide range of stresses (66).

It seems that the mercaptan rubbers should be left in the mouth for as long as is chemically possible if the maximum elastic properties are to be developed before the impression is removed. This is to be distinguished from a prolongation of the curing time caused by a reduction in the relative humidity which will deteriorate the elastic properties at the time of removal from the mouth (59).

Insufficient data has been published for the "syringe type" materials, but this type is somewhat inferior to the "regular type" in its ability to recover after it has been stretched or compressed radically. Thus the use of the "syringe type" materials should be confined to the impression of the prepared cavity, and they should always be reinforced with a "tray type" or "heavy type" material for the most accurate results.

<table>
<thead>
<tr>
<th>Material</th>
<th>Strain %</th>
<th>Set %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5.4</td>
<td>0.8</td>
</tr>
<tr>
<td>B</td>
<td>6.2</td>
<td>1.0</td>
</tr>
<tr>
<td>C</td>
<td>6.6</td>
<td>0.7</td>
</tr>
<tr>
<td>E</td>
<td>9.8</td>
<td>1.9</td>
</tr>
<tr>
<td>F</td>
<td>5.5</td>
<td>0.6</td>
</tr>
<tr>
<td>G</td>
<td>6.9</td>
<td>1.2</td>
</tr>
<tr>
<td>H</td>
<td>4.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Alginate imp.</td>
<td>9.3</td>
<td>1.9</td>
</tr>
<tr>
<td>Agar imp.</td>
<td>8.2</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Fig. 5. Values for strain and set of rubber impression materials after hardening for 30 min. at room temperature (67).

5. Dimensional Stability. — This determination of a substance is related to its property to maintain its dimensions accurately over a period of time under normal environmental conditions. With the rubber materials a shrinkage can be expected for two reasons (65): —

(i) Shrinkage always occurs during a polymerization reaction and the
rubber materials are no exception.

(ii) Whenever volatilization occurs it is reasonable to assume that in an elastic substance such as rubber any voids so made will fill in at a later time.

In the polymerization reaction water is one of the products and therefore the loss of water may produce a further shrinkage (63) (65). Hollenback (70) reported that shrinkage during polymerization has been calculated to be from 0.35% to 0.6%. Distortion then continued rapidly during the first few hours and was probably associated with continued curing of the material. More than one die may be poured in the same impression, the increase in distortion with the number of dies produced may not be due to the mechanical removal of stone dies, but would probably have occurred to the same degree due to the continued polymerization. Shrinkage continues after polymerization, the total in seven days has been evaluated as being from 1.7% to 2.9%. After seven days shrinkage continued, but at a much slower rate (70).

Shippee (71) reported that the second casts made from Thiokol impressions were not as accurate as the original, but the stone surface and detail reproduction were similar. Distortion on standing was reduced somewhat when the double mix technique was employed but was still of a significant magnitude; the bulk of material being less critical with a double mix technique (72). However shrinkage was increased when there was a very large bulk and when this bulk was unevenly distributed (70).

Schnell and Phillips (72) and Skinner and Cooper (67) and Phillips (63) report that when a single mix was used an increase in the thickness of the rubber base material resulted in reduced accuracy. The distortion of this material was studied in air, water and 100% humidity and it was found that the amount of distortion varied somewhat for each material but the general pattern was comparable. Ostlund (73) reported that this contraction was very little and was of no practical importance.

Skinner (65) states that no appreciable change in dimension could be observed before 30 min. after mixing was begun, but that
there was some shrinkage after this time.

The impression material must adhere completely to the tray (whether by holes or by an adhesive) as this probably inhibits the contraction to a considerable extent (63) (65), perhaps within the allowable tolerance limits. It must be remembered also that the more critical the cavity preparation, the more likely it is that any inaccuracies produced will be noticed.

Certainly the dimensional stability of these materials is much superior to that of the hydrocolloids, and a clinically satisfactory restoration can be made on casts poured after $\frac{1}{2}$ to 1 hour (65) (67) (72).

<table>
<thead>
<tr>
<th>Material</th>
<th>Linear dimensional change in</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>30 min.</td>
</tr>
<tr>
<td></td>
<td>(per. cent)</td>
</tr>
<tr>
<td>A</td>
<td>Mercaptan</td>
</tr>
<tr>
<td>B</td>
<td>Mercaptan</td>
</tr>
<tr>
<td>C</td>
<td>Silicone</td>
</tr>
<tr>
<td>D</td>
<td>Silicone</td>
</tr>
</tbody>
</table>

Fig. II.

6. Consistency. — The available mercaptan impression products exhibit a range of consistencies, varying from free-flowing products intended for syringe techniques, to the stiff, heavy-bodied products. The consistency may be compared in the following way: —

A standard amount of mixed impression material, 0.1 ml., is placed between two glass plates and 2 min. after the start of mixing a 500 gm. weight is applied for a further 8 min., making a total of $\frac{16}{2}$ min. from the start of mixing. At this point the average diameter of the resultant flattened disk of impression material is measured.

Consistency values from 28 mm. to 34 mm. are suitable for syringe purposes. The materials with values above 30 mm., however, have a tendency to drip out of the cavities of the upper dentition. Products with values between 19 and 26 mm. are suitable for tray materials.
The consistency of Thiokol is not such that it will displace gingival tissue and therefore the usual means of gingival retraction must be used. The consistency of the impression material will limit the size of the ejection aperture of the syringe nozzle (74).

7. Surface Reaction. — This material does not have any effect on gypsum products, and the surfaces produced on casts and dies are quite hard and smooth. The presence of lumps and nodules is due mainly to the collapsing of bubbles formed in the material during mixing or during polymerization. There is no surface fixing of the impression required before pouring the cast and the impressions can be electroplated.

Storage media of air, water or 100% humidity do not affect the dimensional stability significantly, but Schnell and Phillips (72) found that water should not be used as a storage medium when a plastic tray or shell is used to support the impression material. This was because the tray absorbed water and increased the distortion to three times that produced when stored in air using a similar tray.

The surface hardness of the stone is not greatly reduced when the stone is allowed to set against the rubber impression material. This was explained by Skinner and Cooper (67) who used a Knoop hardness number measurement of seven materials and compared them with a control. The stone dies were also found to be accurate in most instances.

MANIPULATION.

As with other impression materials it is absolutely necessary to follow the directions of the manufacturer. There are two stages noticed when using this material (14).

(i) The paste gradually increases in stiffness without the appearance of any elastic properties.

(ii) The development of elastic properties and a gradual change to solid rubber.

The material must be manipulated and placed in the mouth during stage (i) — this is the manipulation time, — otherwise strains are developed which produce distortion etc. This applies to all
consistencies available. The required amounts which are squeezed onto a mixing pad are usually measured by length, the orifice of the tube controlling the width according to the consistency being used. Equal lengths from each tube should be used.

For mixing purposes a glass slab may be used if desired, but a pad, at least 6 in. square, does away with troublesome cleaning up as the sheet from the pad may be thrown away. The sheet on which the mixing is done must be well fixed to the pad, at least on three sides, to prevent it from folding during mixing and possibly introducing air bubbles or creating difficulty for the ingredients to be properly mixed in the required time. The paper should be of the oil-impervious type, without being impregnated with a substance which might combine with the plasticizers in the paste. There should be no penetration of the paste through the paper while mixing (65). A stainless steel spatula with a blade of about 3 to 4 in. in length and about 1/4 in. wide with a wooden or plastic handle is ideal as a mixing instrument.

Care must be taken during mixing not to let the fingers contact the sticky material. The material must not be left in a hot or humid place before mixing nor should it be mixed in such a place as the setting time will be shortened. It may be preferred that an assistant mix one consistency while the operator mixes the other when using a double mix technique.

Proper mixing is completed when no visible streaks of different colour are present and there is complete uniformity of consistency. As said previously the mixing time is quite critical, small variations producing serious changes in the properties and will lead to inaccuracies. During mixing it may be possible to remove any air bubbles present by spreading the material, keeping the spatula almost parallel to the surface of the pad and using a side to side movement. A double mix technique doesn't produce as many bubbles as a single mix technique.

The syringe or tray may then be filled and the impression procedure carried out. When this is completed the nozzle of the syringe is removed and the excess material in the syringe allowed to set. This
may then be cleaned out relatively easily.

SILICONE BASE MATERIALS.

These materials are the most recent to be used as dental impression materials of the elastic type and a variety of them have been used. Each silicone (elastomer) differs in its physical properties, and most of them have some defects as impression materials. There are four basic problems which have been found with these materials (14).

(i) Short working time
(ii) Poor shelf life
(iii) Gas production during polymerization
(iv) Too great a flexibility to withstand laboratory manipulation satisfactorily.

No one material has all these defects, but the presence of any one makes the material unsuitable for routine clinical use. Recent improvements have been made in many products, with the reduction or total elimination of these defects and it is likely that further refinements will be made.

COMPOSITION AND CHEMISTRY.

McLean (75) describes the chemistry of the silicones. They are a group of resins, oils, and elastomers derived basically from two elements, silicon and oxygen linked together thus: –

```
| – O – Si – O – Si – O – |
```

This is a siloxane chain. The simplest polyorganosiloxane is methyl silicone which is composed entirely of siloxane chains with methyl groups attached to the siloxane atoms: –
The silicone oils, elastomers and resins are built up from three structural units.

<table>
<thead>
<tr>
<th>Monofunctional</th>
<th>Difunctional</th>
<th>Trifunctional</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₃</td>
<td>CH₃</td>
<td>CH₃</td>
</tr>
<tr>
<td>CH₃ — Si — 0 —</td>
<td>— Si — 0 —</td>
<td>— 0 — Si — 0 —</td>
</tr>
<tr>
<td></td>
<td>CH₃</td>
<td>0</td>
</tr>
</tbody>
</table>

The monofunctional unit can end a siloxane chain but not extend it. The difunctional unit will build chains or rings and the trifunctional unit may form cross linkages. Methyl silicone polymers may now be constructed, in theory, by assembling the appropriate structural units. Thus a moderate chain of difunctional units ended by a pair of monofunctional units would be an oily liquid (silicone lubricants). The elastomers are built up from long chains of difunctional units, ten thousand or more being necessary in the chain to constitute an elastomer.

Partial cross linkage between the chains form molecules of high molecular weight which are the basis of the silicone impression materials. The addition of heavy metal alkyl carboxylic acid salts with alkyl silicates is used to manufacture a cold-curing rubber impression material.

These dental silicone rubbers probably consist of a partially polymerized polydimethyldisiloxane mixed with a filler to form a paste, to which is added a liquid catalyst composed of an ethyl silicate containing an accelerator such as dibutyl tin dilaurate. The filler may be zinc oxide, chalk, asbestos flour, dextrin, starch or cellulose (76).
In this reaction hydrogen is given off and may be of sufficient quantity to cause pitting of the stone cast; which, however, is minimized by the introduction of hydrogen acceptors such as aldehydes or chromium oxide (63) (65). The chromium oxide is indicated by a green colour to the paste and an aldehyde is usually identified by its odour.

Skinner (65) reports that the disadvantage of the hydrogen evolution can also be avoided by use of a different type of siloxane base such as: –

\[
\begin{align*}
\text{CH}_3 \\
\text{X} - \text{O} - (\text{Si} - \text{O})_n - \text{X} \\
\text{CH}_3
\end{align*}
\]

where X is the reactive group. An organic tin compound is employed as the accelerator and the cross linkage is obtained through the X groups instead of the methyl (– \text{CH}_3) groups.

The selection and proper combination of the fillers is important since the viscosity and the physical characteristics of the final product are largely determined by this factor; the dimensional stability being mostly influenced. Mostly the accelerator is provided as a coloured liquid, although one product supplies the accelerator in paste form. It is preferable that the accelerator and the paste be of contrasting colours so that the progress of the mixing to a uniform colour can be observed.

**Properties.**

The silicones are irreversible impression compounds which have little taste or smell. Their colour is pleasant, they are fairly attractive to the patient, they can be electroplated and have cleanliness of manipulation. During mixing they are very sticky but do not stain linen. They give a slight tingling sensation to the
mucosa similar to that given by some brands of toothpaste (62). Although the basic silicone gum is relatively weak, the use of a silica filler has increased the strength of the silicone rubbers. The toughness of the silicones exceeds that of all the other elastic impression materials (74). Hollenback (77) in 1957 considered them to be greatly superior to all other impression materials.

1. Surface Detail and Reproduction. — Reproduction of cavity detail is a function of the impression material and the surface condition of the impression and model (63). As with Thiokols, the silicones are excellent in their capacity to register minute surface detail.

Ayers et al (78) conducted tests to evaluate the surface reproducibility of the elastic impression materials based on observations in two different Dental Schools. The test indentations used varied from 34 to 422 μ. The results from both Schools had a similar trend being that silicone was only just inferior to Thiokol in surface reproduction ability; the Thiokol material obtaining the best results; and that the ability of these impression materials to register detail from the original die exceeded the reproduction capabilities of the gypsum casts.

2. Setting Times. — The setting times of the silicone materials tend to be shorter than those for the mercaptan materials (14) (62) (65). The same two stages of initial and final set can be detected in the silicones, although with many materials the point of initial set is not easily detected. The silicones are not so sensitive to changes in temperature and humidity as are the Thiokols (14) (65). The influence of varying room temperatures on the working time of a typical syringe type silicone product in comparison to mercaptan materials is shown in Fig. 2. Over the temperature range of 70°F to 80°F only 0.5 min. of working time is lost as compared to 4 min. lost by the mercaptan product over the same temperature range.

The setting time of the silicones can be controlled by the amount of accelerator employed, but the relation between the accelerator added and the working or setting time is by no means proportional. In general, the retardation obtained by reducing the amount of accelerator
is more marked than the acceleration obtained by increasing the amount of accelerator beyond a certain limit (65).

McLean (75) states that an increase of catalyst content by 50% will accelerate the polymerization and shorten the setting time by 2 – 3 mins., consequently the development of elasticity is also hastened. He also reports that it is impossible to give a specific setting time for the silicone rubbers since these materials continue to polymerize long after the manufacturer's stated setting time has elapsed; also that sufficient elasticity has not developed unless a mixing and setting time of 8 – 10 min. is adopted.

Myers and Peyton (79) found that the initial setting times of the silicones varied from 2.5 min. to 10.5 min. and the final setting times from 5 to 15.5 min. in a series of tests conducted. The initial set of a syringe material which was included in these tests was found to be longer than it was able to eject the same material with normal
hand pressure from a syringe. Tests conducted by ejecting this material every 30 secs. from a syringe revealed that although the vicat needle initial set was 10.5 min., the material could not be ejected after 6.5 min.

With many silicones a reduction of the catalyst concentration or quantity to give clinically convenient working times for syringe use results in incomplete setting and the development of a tacky surface. A recommended curing time of 10 min. is, therefore, somewhat of a compromise between a practical curing time when the materials are setting in a patient's mouth and a curing time which would result in maximum accuracy of reproduction (80).

3. Shelf Life. — This is a much more critical factor with the silicones than with the Thiolks. The fact that the silicones are supplied as partially polymerized pastes means that the shelf life is not unlimited and storage periods of three months or more may affect the consistency (75). Some products undergo fairly rapid aging with the result that in a few months the setting reaction fails to go to completion and the resulting impression is soft and sticky.

Other difficulties encountered 12 months after the material had been obtained in the Department of Operative Dentistry, University of Sydney, were extreme difficulty of ejecting the base paste from the tube. This tube had a screw top which had become loose and which may have accounted for the shortening of the shelf life. Another product which had the base in separate sealed tubes, each tube sufficient for one use, did not have this difficulty of ejection but when mixed with the specified amount of catalyst and retarder resulted in a prolonged setting time which was in the region of 18 hours. This assumes that something may have affected the catalyst. This is the usual experience found in using most silicone products.

Another material resulted in an increased viscosity and a stiffer mix when the catalyst was added, thus enhancing the difficulty of injection technique. This also reported to occur by McLean (75) who suggested that the tubes be stored in a cool place and the screw cap be replaced after use before mixing was begun.
This short shelf life is not experienced with the mercaptan base materials although their shelf life is not unlimited. Skinner and Cooper (67) found that there was no significant change in the setting times of mercaptan base when stored on the work bench during experiments over a period of 5 months in 1954.

4. **Consistency.** – There is a range of consistencies available with the silicone products and these can be examined with the modified slump test as described with the Thiokols. Values of the order 28 – 32mm. have shown to be satisfactory for syringe materials and the stiffer pastes with values of 15 – 24mm. serve well as tray materials (14) (79).

The silicones resemble art erasers in consistency when set (62) and have a fairly high viscosity. They seem to become more viscous as the shelf life is increased. As stated previously the type of filler used affects the viscosity of the material. A recent development has been the provision of a less viscous grade of silicone rubber which will allow a smaller ejection aperture to be used in the nozzle of the syringe (74). However the accuracy of these less viscous types may not be sufficiently high, and the use of either an extremely low viscosity material or a mass which is unduly stiff will influence the ability of the material to reproduce minute detail (63).

The exact stiffness desired will vary with each material and probably can be determined only through experience.

5. **Gas Evolution.** – This is a disadvantage of the silicones over the other impression materials. The evolution of gas causes pitting of the surface of the cast which affects the surface reproducibility and the accuracy (14) (63) (75) (76).

This was particularly noticeable in the earlier products. The gas evolution – probably hydrogen – declined over 48 hours and at this time a cast could be poured with safety (75). The thicker the amount of impression material used the more gas was evolved and therefore the longer the time that should elapse before pouring (76). However such a time lapse is not practical for dimensional stability reasons. Most of the newer products appear to have overcome this gas evolution by
alteration of the liquid activator.

This gas evolution may also be overcome by the use of hydrogen acceptors and by establishing a different siloxane chain where the cross linkage is obtained through a different group. Another method used by McLean (75) was to place the impression in a vacuum at 28 inches of mercury for 10 min. and then wash it in detergent before pouring. In this way the formation of gas is retarded for a sufficient period to allow the stone to set without disturbance.

6. Elasticity. - The silicone products behave in a manner similar to the mercaptan products when tested for percentage strain and percentage deformation and probably 4% permanent deformation is acceptable under the conditions of a 12% strain test (14). The silicone elastomers are probably the most elastic impression materials yet available to Dentistry and are therefore ideally suited to reproduce deep undercuts (75).

The characteristically long coiled chains of the silicones give these materials their high elastic properties. When such a material is subject to externally applied stress, i.e. during removal from an undercut area of the mouth, the chains uncoil and they tend to become aligned parallel to the axis of elongation. If this doesn't exceed the yield value the chains recoil and elasticity results. If the force applied does exceed the yield value, sliding between the chains occurs and permanent deformation can be induced.

7. Dimensional Stability. - The silicones shrink during polymerization to a greater extent than do the Thiokols. This can be shown in Fig. // page 43. This is probably due to the volatilization of certain ingredients as described previously as well as to the polymerization reaction. Storage of the silicones before pouring the cast is contra-indicated (63). The cast should be poured immediately (80).

There has been a suggestion (75) (76) that there should be some delay in pouring a cast so as to allow the gas evolution to cease, and thus produce a better surface on the cast. It seems that a more satisfactory arrangement is to eliminate the gas by other means rather than wait so as not to introduce errors due to the material's lack of
complete dimensional stability.

The bulk of material used is of significance in that the larger the bulk the larger the inaccuracies (76) (80), and, when in a tray, the greater the part unrestrained contraction plays in dimensional stability. This may be as much as 1.2% over a two week storage period. A close fitting and well perforated tray decreases this shrinkage by exercising a restraint on the materials (75). This was supported by Shipee (71) who found that the most consistently accurate results were obtained with silicones when an acrylic tray with one thickness of baseplate wax as spacer was used, and which was loaded with a low viscosity material and used in combination with an injection technique.

Hollenback (77) reported that silicone base material was greatly superior to all other types. He found one product (81), manufactured in Germany, but which has since been removed from the market, to excell in accuracy and dimensional stability as tested by his method explained on page 8, see also Fig. 1 p. 3a. He also reported (77) that the cast accuracy was excellent and the impression can be stored for a considerable length of time without losing this accuracy; thus allowing several casts to be run all with equal accuracy. This is contradicted by Gilmore, Schnell and Phillips (80), whose evidence seems to be more convincing, and who stated that the distortion increased with each die poured in a silicone and is greater than with consecutive dies made from a Thiokol impression.

The coefficient of Linear Expansion over the range 15° - 40°C of three silicone materials was found to be 0.00018, 0.00021 and 0.00020 per centigrade degree. These values are comparatively high being twice those of the acrylic resins (82). This means that an impression taken in the mouth will have a linear contraction of 0.3% when removed which is in addition to other changes. Thus to reduce the dimensional changes the impression should be cast at mouth temperature.

In all experiments on dimensional stability the direction of the dimensional change is of interest and depends on whether the impression material is attached to a tray or not. This is so with all elastic
impression materials. If attached to a tray the direction is towards the tray which produces a larger cast; when unattached the material contracts so as to produce a smaller cast (76) (82).

The effect of humidity on silicones results in small dimensional changes, there being generally a very slight expansion (82).

8. Surface Reactions. - Those products which produce gas during polymerization usually result in defective stone casts, the surface of which is porous. The occurrence of surface porosity is somewhat irregular for which reason several good models may be followed by a number of porous ones from impressions taken with material from the same tube (14). The gas produced has been discussed in a previous section. Castings poured at mouth temperatures have improved model surfaces (82).

The silicones do not appear to cause any deterioration in the surface hardness of stone models. A comparison of the surface hardness of two stone materials conducted by McLean (75) poured into two silicone impression materials shows no significant difference between the stone poured against a glass surface and against the impression surface.

MANIPULATION.

The procedure for the silicones is essentially the same as for the mercaptan products. The catalyst may be dispensed in liquid form or in a paste form. The base and catalyst should not be placed in contact before mixing is begun and the areas to be impressed should be dry and free from all debris.

The silicones are slightly easier to mix than the Thiokols; however, when the catalyst is a liquid care should be taken that the few drops used are dispersed through the silicone base. Failure to do this will result in incomplete polymerization in some areas. Areas of stickiness may also result. A similar type of mixing pad and spatula as described for the Thiokols is suitable for the silicones. Air bubbles do not seem to cause as much trouble as with the Thiokols. The manufacturer's directions should be rigidly followed if consistent results are to be expected.
RUBBER IMPRESIÓN MATERIAL SPECIFICATION.

This has been proposed by Miller Jr. et al (83) which provides for both types of rubber materials and lists requirements of uniformity in consistency and freedom from impurities and poisonous ingredients. The mixing time should not be more than 1 min. and the working time not less than 2 min. Details for sampling batches are supplied, and detail reproduction and compatibility standards are set. The elastic qualities are defined by a 12% compression test resulting in not more than 4% permanent deformation. The linear change of a specimen after 6 hours should not be more than 0.2%. Shelf life is tested by ageing a sample at 60°C for 1 week at the end of which time permanent deformation following the 12% strain test must not exceed 4%.

The specification concludes with recommendations on the packaging and the type of instructions to be supplied by the manufacturer.

AN EVALUATION.

The silicones offer the advantages over the mercaptan base materials of cleanliness in handling, less sensitivity to temperature change, less toxicity when in continuous contact with the tissues and are not as sticky (63) (65). They are easier to mix, have aesthetic colouring and do not stain linen as do the Thiokols. When set they are stronger than the Thiokols (62). However they have the disadvantages of a more rapid setting time, less dimensional stability and a shorter shelf life. They are a little inconsistent, some products having poor elastic qualities or being too soft and flexible while others evolve gas which causes casting failures.

These shortcomings are probably due to the short time the silicones have been in use and will probably be improved with a little more experience in their manufacture and manipulation.

According to Phillips (63) the accuracy of both silicone and mercaptan base materials is dependent on:

(i) Use of minimum amount of material.
(ii) Having the impression material well bonded to the side of the rigid band or tray.
(iii) A minimum curing time of 8 min. in the oral cavity.
(iv) Use of a double mix technique with syringe wherever possible.
(v) Pouring the cast as soon as possible.

The rubber materials are clinically as accurate as the agar hydrocolloids, they are more easily prepared for use and have greater dimensional stability. They can be electroformed to give metal dies when required, whereas the agars are electroformed with difficulty and with the possible introduction of sources of error. Compared generally with the hydrocolloids, the stronger structure of the rubber materials at the surface of an impression, coupled with their non-reactivity with gypsum products (except for a few silicones) allows for a better surface reproduction.

There is no special equipment required for the rubber materials, no boiling, tempering or storing and it is not necessary to pour the cast in the first few minutes. However alginites are cheaper, and once the initial expense of the agar hydrocolloid equipment has been overcome these materials may be used with relative ease and with excellent results.

The successful impression serves as a means to obtain the die or cast, and the type of impression material employed is related to both the type and quality of die or cast that is produced and also to the case under consideration. Peyton et al (14) list the qualities of the Elastic Impression Materials as in Fig. 13 a & b.
<table>
<thead>
<tr>
<th>Material</th>
<th>Agar</th>
<th>Alginate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of</td>
<td>Boil, temper, store</td>
<td>Mix water and powder</td>
</tr>
<tr>
<td>Preparation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stability of</td>
<td>Up to 1 hr. at 100% R.H.</td>
<td>Pour immediately</td>
</tr>
<tr>
<td>Impression</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of Die or</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Cast )Stone</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of Die or</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cast )Metal</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of Handling</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical Factors</td>
<td>Boiling, storing,</td>
<td>Proportioning,</td>
</tr>
<tr>
<td></td>
<td>tempering, cooling,</td>
<td>mixing, removal,</td>
</tr>
<tr>
<td></td>
<td>removal, storage</td>
<td>storage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reproduction of</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>Detail</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

Fig. 13 a.
<table>
<thead>
<tr>
<th>Material</th>
<th>Mercaptan Rubber</th>
<th>Silicone Rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of Preparation</td>
<td>Mix two pastes</td>
<td>Mix two pastes, or paste and liquid</td>
</tr>
<tr>
<td>Stability of Impression</td>
<td>Up to 1 hr. on bench</td>
<td>Pour as soon as possible</td>
</tr>
<tr>
<td>Type of Die or Cast )Stone</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>)Metal</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td></td>
<td>x ?</td>
</tr>
<tr>
<td>Ease of Handling</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td>Critical Factors</td>
<td>Proportioning, mixing, close fitting tray, removal</td>
<td>Proportioning, distribution of catalyst, close fitting tray, removal, shelf life</td>
</tr>
<tr>
<td>Reproduction of Detail</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Excellent</td>
<td>Good</td>
</tr>
</tbody>
</table>

Fig. 13 b.
CHAPTER 111

Techniques

The direct technique makes it difficult in Crown and Bridgework to produce restorations with perfect gingival adaptation and perfect proximal contour. This is because of limited access, restricted visibility, temperature variables and the necessity of stabilizing the wax mass. The indirect technique overcomes these difficulties.

In reviewing the techniques associated with the elastic impression materials it must be assumed that the proper examination and diagnosis has been carried out, the mouth is radiographically sound and clear, the patient is happy as far as type of treatment and cost is concerned, and that study models have been obtained.

It may not be possible to use each of the elastic impression materials or the techniques associated with their use for every purpose and by every operator with equal results. Excellent results can be obtained by the various direct and indirect methods or combinations thereof, and these should be known so that the best advantage can be taken of them to produce the best possible results by selecting the one best suited for the case being treated (56).

The factors which influence the type of technique to be used for a given case are:

(1) The type of patient,
(ii) The location of the proposed prosthesis in the oral cavity,
(iii) The condition of the prepared teeth,
(iv) The ability of the operator to manipulate the necessary materials,
(v) The value of the dental chair time,
(vi) The ability and value of the assistant,
(vii) The quality and quantity of available laboratory assistance.

ADVANTAGES AND DISADVANTAGES.

HYDROCOLLOIDS.

The advantages and disadvantages of the agar-agar type of hydrocolloid have been proposed by various authors (31) (32) (40) (54) (84) (85) (86) (87), which may be collectively listed as follows:

Advantages.
1. In mouth reconstruction all the abutment preparations may be accurately reproduced with their proper relationships to each other in the arch. The dies may be more correctly articulated because of the full cast obtained.
2. The use of agar conserves the patient's time by the construction of multiple inlays or bridges etc. if necessary.
3. May conserve the dentist's clinical time, especially if there is a lot of work to be done and if the equipment is previously set up.
4. Only one impression need be taken.
5. A high degree of accuracy is possible and each stage can be checked back on the cast. If handled correctly there is greater accuracy on long span cases.
6. Present day equipment and materials have been highly improved simplifying the technique greatly.
7. The use of agar allows the dentist to utilize the technician to the fullest extent.
8. The major finishing of the restoration can be accomplished beforehand.

9. Errors of making a Copper Band impression, packing an amalgam die, taking plaster records etc. are eliminated.

10. Many variables associated with agar are mechanically controlled, resulting in less handling and less chance of human error introduced.

11. There is less variation of the quality of the material than is present with the alginites.

12. Reproduction of detail is very good.

13. Agar is the only medium which makes possible a technique possessing the accuracy of the direct method and the convenience of the indirect.

14. Agar can be used in any type of restoration with walls perpendicular to the occlusal surface.

15. Agar can be used in any type of Bridgework, in Precision Attachments and in Partial and Full Denture work.

Disadvantages.

1. The technique is not foolproof and any slight carelessness can produce errors.

2. Must have the proper equipment.

3. The impression surface needs fixing and the stone dies are more fragile than those made from electroformed impressions.

4. The impressions are rather difficult to electroplate.

5. An assistant and a technician are required for the proper use of this technique.

6. There is a possibility of injuring the tissues by burning or by the method of gingival displacement.

7. If individual dies are poured, there is a chance of the remaining parts of the impression of becoming distorted while the stone dies are setting.

8. The agar material cannot be used unless the cavity margins are visible.
9. The technique will fail if there is not complete dryness of the field.

It has been shown in Chapter 1 that it is also possible to obtain accurate results by the use of the alginate impression materials. Because of the greater number of variables associated with these materials from batch to batch, in their manipulation and in their technique, the agar-agar type is usually preferred.

The specific merits of the alginate as distinct from the agars (31) (32) (56) (88) (89) are the following:

1. There is less equipment required. The required equipment is not as complex.

2. There is a slightly less complex technique and manipulation procedure associated with their use.

3. They are somewhat easier to master.

4. The alginate gels first where they contact the oral tissues because the temperature is higher here than in the tray. The agars, however, require cooling and the tray section gels first. It may be an advantage for gelling to take place first where the material is in contact with the tissues as the chances of distortion in the areas may be reduced.

5. Alginate is contra-indicated when all margins of the prepared teeth are not visible. In these cases a technique employing a material and procedure which will displace tissues should be adopted.

6. In individual batches of the alginates there is no doubt that more variations exist than with the better commercial agars.

RUBBER BASE MATERIALS.

The rubber base impression materials - Thiokols and Silicones - eliminate most of the undesirable features of the hydrocolloids and none of the desirable ones (90). Their advantages and disadvantages (67) (87) (90) (91) (92) (93) (94) (95), may be listed as follows:

Advantages.
Advantages.

1. There is good stability against flow and distortion over a period of time and less variation in results than with the agar.
2. Good elastic properties. They are able to reproduce minute detail and large undercuts.
3. Meagre armamentarium required to handle these materials apart from the syringe and the apparatus is readily available.
4. They can be silver plated relatively easily.
5. They are easy to prepare and use.
6. There is adequate working time for all uses.
7. The impression is taken at room temperature - no fear of burning the patient.
8. They flow readily and are of good consistency and need no pressure during the taking of impressions.
9. They are non irritating to oral tissues.
10. They present a tough surface and resist rupture during removal.
11. The shelf life of the Thiokols is very good.
12. There is no effect on stone casts, except for a very few silicone products.
13. The surface hardness of the stone dies is not greatly reduced when allowed to set against them.
14. They can be used in multiple impression techniques.
15. May delay pouring the cast for a short period if necessary without dimensional change; (when used in conjunction with compound or wax this is not the case).
16. It is possible to pour more than one cast from the same impression.
17. The clinical time for the technique is not extensive.
18. The adjustment of the restorations at the chair side is reduced.

Disadvantages.

1. The gingival margins of the preparations must be exposed to be recorded.
2. It is difficult to obtain a rubber base impression if access is poor and impossible if the field cannot be kept dry.
3. The Thickols have an unpleasant odour.
4. The Thickols have a dirty brown colour.
5. The Thickols stain linen permanently.
6. The Silicones have a very poor shelf life.

Uses.

Eastman (96) reports that the rubber materials are not a substitute for the agars in a surgery where the required equipment for the agars is available; the rubber materials are best suited where only a few inlays, crowns and bridges are made each week; and that the rubber materials can be used in an individual tray for one or more preparations or in a Copper Band for a single tooth impression.

The successful use of the rubber base impression materials depends upon (90): –

(i) The retraction or removal of all interfering gingival tissue,
(ii) The use of a properly constructed tray,
(iii) Absolute dryness of all teeth included in the impression,
(iv) The insertion of the material into the cavity without trapping air bubbles,
(v) The thorough mixing of the ingredients of the impression material.
(vi) The thorough setting of the impression material before removal from the mouth.

MOUTH PREPARATION.

It is very important that the tooth preparations are properly done. Gross irregularities of bur and stone cuts on the preparations must be reduced – the shoulders should be smooth, uniform and well defined. Basset (97) goes so far as to say, "It will be found helpful to clean each cavity with fine pumice, using a rubber cup or end brush before the impression is made. If this is done the margins will appear much sharper on the stone dies."
Careless preparations are unmasked by the elastic impression materials and therefore the excellence of these impression materials is no compensation for bad cavity preparation.

It should also be stressed that the patient must be comfortable in the chair and that the chair is positioned correctly to enable the operator to carry out his task (a) without assuming tedious positions and (b) to use all available means of vision etc. to the fullest advantage. In addition all required instruments and equipment should be ready, and if an assistant is required they should know what is to be done beforehand so as to help with maximum efficiency.

Because of the extreme ease with which the elastic impression materials can record minute detail, the area to be impressed must be clean of all debris, blood and saliva and the preparation dried (98) (99) (100). This may be done by rinsing, swabbing and drying with warm air. The manufacturer's directions should be followed as one or two of the rubber products have the tendency to stick to dry surfaces and therefore require a slightly different procedure.

Better impressions may be obtained by the use of salivary inhibitors; or small amounts of astringents. Hedegård and Nyquist (101) obtained casts from hydrocolloid impressions after spraying the area beforehand with an aqueous solution of:

- 0.02m Ascorbic acid
- 0.25% Sodium Bicarbonate
- 0.00075% Calcium Sulphate
- Peppermint water.

They found that casts obtained with the use of this mucin solvent and wetting agent had significantly better reproduction of surface detail than casts obtained when ordinary water was used as a spray.

Lepley (102) advocates the use of impression plaster in dilute solution as a pre-impression rinse for hydrocolloid impressions. The plaster dissociates into calcium hydroxide and sulphuric acid according to the following equation:-
\[
\text{CaSO}_4 \cdot 2\text{H}_2\text{O} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{H}_2\text{SO}_4
\]

The dissociation constants of calcium hydroxide and sulphuric acid are 0.21% and 0.17% respectively. This presents a reasonable basis for the production of a neutralizing effect on the oral fluids. The pH of the oral fluids varies from 6.7 to 7.8 and the dissociation of the plaster into simultaneous basic and acidic constants would therefore neutralize the oral fluids whether acid or alkaline and a better impression may be obtained. The suspension of plaster particles also acts as a mechanical cleaner, which when forced vigorously between the teeth and over the tissues removes and breaks down the mucin strands of the saliva presenting a "cleaner" surface.

Neither adverse reactions from the patients nor harmful effects on the hydrocolloid have been noted.

**GINGIVAL PREPARATION.**

With the use of the indirect method and the elastic impression materials for either single or multiple procedures, it is desirable to have all margins of the prepared teeth exposed, so that these very critical areas in Crown and Bridgework may be recorded with the accuracy the impression materials offer. This exposure is necessary by the operator because the elastic impression materials cannot push aside the gingiva during the impression procedure.

Both patience and care are necessary as is also a careful examination of the gingival tissues surrounding the prepared teeth. The depth of the gingival crevice varies with age and its pathology, and varying gingival conditions must be recognised, and a suitable method for the retraction of the tissues must be decided upon. Any technique must normally be conservative so that the gingival attachment is not stripped or injured so as to cause permanent tissue recession (6). This is especially important in the anterior region of the mouth.

Perdigon (40) describes four positions of the gingival margin
of tooth preparations.

(i) The cavity margin is not below the gingiva – about 10% of cases.

(ii) The cavity margin is slightly under the gingiva – about 75% of cases.

(iii) The cavity is moderately deep, but the gingival tissue healthy and doesn't need to be removed.

(iv) The cavity margin is deep under the gingival tissue. The tissue is hypertrophied, bleeding and becomes lacerated during cavity preparation and needs to be removed. The removal of abnormal, unhealthy superfluous gingiva is justified (98). The tissue must be forced sideway away from the tooth rather than in an apical direction when removal is not indicated.

METHOD OF TISSUE DISPLACEMENT.

A. Mechanical Pressure. This may be done in a number of ways.

(i) Gutta Percha temporary stopping may be used in the cavity type of preparations and left until the next appointment (40) (98) (99) (100) (103) or may be used for 10 min. under biting pressure before taking the impression at the same appointment (56) (88). Gutta Percha if left for too long a time may leave a raw surface (98).

(ii) With the three quarter and full crown type of preparations, celluloid or aluminium shells filled with ZnO – Eugenol may be placed until the following appointment (56) (88) (98) (100). The danger of this method is that if left too long permanent depression of the attachment can result with a subsequent area of sensitivity and susceptibility to decay (100).

(iii) Rubber dam application may be sufficient to expose the gingival margins of a preparation (6) (56) (88) (99). This has the disadvantage that the surrounding tissues cannot be impressed if so required.

(iv) Orthodontic rubber bands, suitable in size and dipped in Chloroform to retain their elasticity may be placed, being very careful that they are not allowed to remain for a long period of time; 5 - 10 min.
is sufficient (56) (99).

(v) Simple tying of a ligature firmly around the tooth below the gingival margin may be used (6) (56) (98) (99) (104), for 5 - 10 min.

B. Chemical Methods. Unwaxed ligature cord or cotton fibres soaked in various chemical solutions and packed into the gingival crevice may be used.

(i) Adrenaline. Hampson (88) favours string impregnated with 1:1000 solution, while Grey (99), Kahn (105), Perdigon (40) and Bassett (97) use a 1:100 solution. Rubinstein (106) and Thompson (104) use an 8% solution. Clappison (98) combines the 1:1000 adrenaline with 10% trichloracetic acid.

(ii) Zinc Chloride. Again various concentrations have been suggested. Rubinstein (106), Kahn (105), Perdigon (40) and Thompson (107) use 8%. Grey (99) suggests 10 - 40%, Pfeiffer and Jeffreys (56) suggests 5% while Hampson (88) and Herman (100) vary concentrations from 5 - 40%. Hohlt (39) uses 35%.

(iii) Alum solution, saturated, may be used similarly to adrenaline (99) (107). The dry crystals will absorb seepage, and through the styptic action of the chemical, seal off the capillaries (104).

(iv) Tannic acid 20%. The use of this chemical has been suggested by Thompson (107).

(v) Ferric subsulphate (Monsel's powder) may be used. This has been used by Thompson (107) and Grey (99).

Application of these chemicals must be carefully executed in order to prevent sloughing of the gingival tissues. They should be applied for about 3 min., after which time the area should be examined and, if necessary, fresh applications be made for a further 1 or 2 min. With the weaker concentration of astringents the string may be left in place, even while the impression is being taken (6) (88).

These chemical methods become difficult when the proximal portion of the preparation is deep since it requires an increasing amount of shrinkage of tissue to expose the margins. The use of high concentrations of epinephrine on lacerated gingival tissue carries with it the possible
hazard of absorption of enough epinephrine to produce a systemic effect (106). Similarly strong solutions of ZnCl₂ produce an escharotic effect. In such cases of deep proximal cavities a Copper Band technique may be used with greater advantage.

The thickness of the string or the cotton fibres which are used are dependent on the conditions of the gingiva and the amount of gingival retraction required. When mild haemorrhage persists a few drops of ferric chloride or adrenaline may aid in its control (99).

To obtain the retraction of gingival tissues, the tooth is protected from moisture with a cotton roll and the area is dried carefully. A length of string about the circumference of the tooth is cut and tucked carefully into the crevice with a blunt instrument. Pressure is directed obliquely against the long axis of the tooth rather than towards the apex of the root. When carried into the gingival crevice the cord not only retracts the gingival tissue, but the exudate of the gingiva dissolves the drug and its styptic action is utilized to keep the area dry (6).

It is not necessary to tie a knot in the string, although it may help in some cases. A piece of wax may be used to hold the ends of the string together.

It is usually necessary to have the mouth rinsed after the gingival retraction is complete in order to remove any saliva or blood and excess chemicals which may have collected. This should be done quickly and the preparations dried again while the impression tray is being loaded.

C. Removal. This may be necessary in order to combat hypertrophied gingival tissue, or to increase the clinical length of the submerged crown. This tissue may be removed by either electric cautery, surgery, or chemical cautery (6) (40) (88). During these procedures only the epithelial tissue should be removed and not the connective tissue (99).

(i) Electro-cautery. This may have to be used in conjunction with anaesthesia. The patients may object to electrocautery because of the odour produced. Only a V-shaped trough should be formed, and care should be taken not to remove all the interproximal papilla.
(ii) Surgery. This procedure is similar to that of a gingivectomy.

(iii) Chemical cautery. This is achieved by using string impregnated with 40% zinc chloride or sodium sulphide or potassium hydroxide (6). Caution is necessary that these chemicals be applied for 2 – 3 min. only, as longer applications will cause excessive tissue destruction and sloughing (104). The tissue should then be treated with a mild antiseptic.

Following all radical removal of gingival tissues, proper surgical precautions should be followed by placing a pack of ZnO – Eugenol for a few days to allow proper healing. The impression may be taken at the time of removal of the tissue, provided that the bleeding etc. can be controlled, or it may be taken after healing has been completed.

Various combinations of all the above methods may be used depending on the conditions prevailing in the mouth.

EQUIPMENT.

The necessary equipment is of the utmost importance when handling the elastic impression materials in Crown and Bridgework. The type of equipment required for each material is determined by the characteristics and properties of the material and the task the material is asked to perform. Only the specific equipment will be discussed.

A. AGAR-AGAR

The proper equipment is indispensable in this technique from the standpoint of economy of operation.

1. Conditioners. These are thermostatically controlled units in which three compartments are provided so that the three temperatures necessary for boiling, storing and tempering the material are accurately maintained. These are supplied by various companies and thus are produced in various designs and have been reported by various authors (29) (40) (84) (88) (97) (103) (108). These conditioners may also be "home made" (109)
The three compartments are maintained at predetermined temperatures: (a) at 212°F for liquifying the agar, (b) at 145°-150°F for storage of the material (for hours if necessary), and (c) at 115°F for tempering the material for a few minutes before injecting into the tray (84) (108). The conditioners may be turned on at the beginning of the day, the material boiled and then stored until required. The assistant should check to see that the water in each of the compartments is at the correct level.

2. Syringes. Two main types of ejecting apparatus are used in the agar-agar technique. The larger bore ejector may be a syringe type or Dentocoll gun type, into both of which may be placed large cylinders of previously prepared agar and liquified. This is then used for filling the tray. The Dentocoll gun type is rather clumsy and it needs two hands to operate. A smoother technique may be developed with the syringe type of ejector. Morrant and Makinson (29) use a modified Edwards Ear Syringe.

There are specially made smaller bore ejectors or syringes which are used for injecting the material into and around the tooth preparations. These, too, may be obtained in different designs. The usual types supplied are similar to local anaesthetic syringes except that they may be made of a laminated plastic material which doesn't lose as much heat as do the metal type (109). These consist of a plunger inside a barrel to which a nozzle is attached, - the Thompson type (84) (97). The heat loss from the all metal syringes has been prevented to some degree by placing a rubber sleeve over the barrel. This rubber sleeve also protects the patient and operator from being burnt if the agar has not been tempered properly (40) (103). The syringe must also be able to stand boiling without being damaged.

A cartridge syringe may be used with the empty carpules being filled with agar (29) (109). Perdigon (40) recommends a Hannau syringe to be used with a Hannau conditioner. This syringe is equipped with an air release valve so as to eliminate any trapped air.

The agar hydrocolloid is usually placed into the syringes in sticks and the material then liquified or it may be aspirated from a
container of liquefied agar. Bate (110) describes a syringe into which agar can be aspirated quickly and easily and without the inclusion of air. This has a simple bayonet catch for the nozzle which can be removed, and a loose plunger which allows any air to escape and prevent an air lock. It is also easily cleaned.

The nozzle of the small syringe is an important part. It must be small enough to deposit agar in the gingival crevices and into the bottom of cavity preparations, without being so small as to "clog up", and it must not obstruct vision during the technique. The size of the nozzle depends on the type or size of the cavity preparations and may be of an interchangeable variety; the size being either 18, 20, or 23g (40). Other authors (29) (88) (103) suggest similar gauges.

Pruden (111) reports that a Thompson syringe with a 21 gauge nozzle is too big for injecting into a pin hole made by a 700 tapering fissure bur. This 21 gauge nozzle may be cut off near the shaft of the syringe and a 25 gauge carpule needle can be snugly telescoped into the 21 gauge stump, which may then be used for the pin hole type of preparations. However, in order that the agar may flow through such a small aperture its temperature at the time of ejection should not be less than 135°F.

Mann (28) reports that when Sears first used his technique he used empty Novocain Carpules with a dilute solution of agar and an 18 gauge needle.

Manufacturers then made all metal syringes and metal syringes with plastic covers which could be filled with standard size blanks of injection agar and boiled. With the advent of the thermostatically controlled water bath, introduced by Thompson in 1938, standardization was accomplished. Also improvements in the type of tray agar have eliminated the mixing gun to a great extent although it is still used.

3. Trays. The tray must have a high modulus of elasticity and a high elastic limit. It must be stiff enough not to be distorted elastically during its application (when filled) over the region to be impressed, it should not distort during the setting of the impression material, and it should not distort during its removal after the
impression material has set (112). The water cooled trays used to contain reversible hydrocolloid have both a sufficient modulus of elasticity and an adequate elastic limit. The proper clearance between the teeth and the tray is also important, because there must be sufficient space to allow the elastic properties of the impression material to be utilized but not so much as to create an uneven distribution and produce distortions. 3mm. space is suitable for clearance (84) (112).

As water cannot be circulated in a plastic tray, this type is not used with agar hydrocolloid. The trays used have provision for water circulation and are of the "stock" metal type, the handles of which are the water inlet and outlet pipes used for attachment of the rubber hoses to the water supply and to the sink. They may be of the full arch or sectional type, the latter being used on either side of the mouth - upper or lower - and others used in the anterior region. They may be either perforated or non perforated or of the rim lock variety.

Essentially the tray selected should be oversized to avoid thin sections of agar and it should have greater contour labially and buccally to accommodate the muscle attachments. The upper full arch type should have a higher palate than usual and the lower full arch type should have long lingual flanges and short, rounded disto-buccal borders.

The trays must be post dammed with compound or wax, with stops and guides - again in compound or wax - on the teeth other than the abutments and only if necessary on the tissues (40) (84) (98). As agar hydrocolloid can only be held in a tray by mechanical retention, this compound or wax is necessary, particularly when using the non perforated trays (103). These stops and guides are placed to assist the proper centering of the tray in the mouth when full of impression material, to confine this material and to prevent the tray from being carried against the occlusal surface of the teeth.

Getz (113) reported a tray which overcomes the problem of articulation variations when the case is mounted. This is the Checkbite
tray which is a sort of rigid bite former with perforated walls which are held rigidly in one unit by a connecting bar which passes distal to the last tooth in the arch. Extending connections for attaching rubber hoses for circulating water form the handle. A slot provides a means of retaining a piece of fibrous paper at the plane of occlusion in the area where the proposed prosthesis is to be fitted. Mira cloth is readily available and is ideal for this purpose because of its strength when wet and because the fibres retain the impression material. The interocclusal record for molar–bicuspidx region on one side is made at the same time that the impression is taken i.e. in one step. These trays are available for anterior sections or full mouth impressions and can be attached to a face bow.

B. ALGINATES.

The only equipment required when using alginate in Crown and Bridgework apart from an interval time, a clean plaster bowl, a spatula and W/P ratio measures, is a syringe of essentially similar design to those described in the preceding section. Because of the nature of the reaction of the alginate the syringe should be of a type which can aspirate the impression material, as previously prepared blanks of alginate are impossible.

Trays. The "stock" tray types described in the preceding section may be used with the alginates, the water cooling system not being required. Similar compound or wax stops and additions are placed to produce a uniform 3 mm. thickness of material.

Pfeiffer (114) prefers the non perforated rim lock trays when using alginates because the tray aids in carrying the impression material into intimate contact with the preparations and involved structures. Perforated trays are usually indicated in substances involving soft moveable tissue in vital areas.

The alginates allow for the use of acrylic, polystyrene or alluminium impregnated shellac individual trays. These may be uniformly spaced from the area to be impressed complete with stops and perforations. They may be made on the study casts before the
Fig. 14.
Wisps of Cotton Wool Used for Retention of an Alginate Impression.
preparations are completed.

The methods of adhering the alginate to the tray vary, the most usual way being by use of the perforations in the tray combined with the compound or wax stops and sealers. Seear (89) lists the following ways when using unperforated trays:

(i) Adhesive tape may be placed on the surface of the tray,
(ii) Sticky wax dripped onto the tray. This method is also suggested by Atkinson et al (50),
(iii) The use of sticky wax with the addition of cotton wool wisps before the wax hardens.

Banger (115) examined various trays for use with the alginates and found that the "Jescoform" and "Jescoplast" trays were best suited. These trays are non perforated, have special notches for any probable muscle attachments, have marginal curves which rise sharply on both sides of each of these notches and for retention of the material spiral springs around the margin are used. The tray handles are of good shape and are fitted to the bottom of the tray permitting easy manipulation.

As has been stated previously, Chapter 1, the storage of both agar-agar and alginate impressions is not recommended. However, if storage is required for a very short period of time these impressions may be placed in a humidor which tries to keep the humidity at 100%. This is done in the Department of Prosthetic Dentistry, University of Sydney. Another storage compartment is a Hygroper (89), which is an airtight vessel having a felt pad soaked in water on which the impression may be placed.

C. RUBBER BASE.

Similar equipment may be used for both the mercaptan rubber base and the silicone impression materials.

1. Syringes. These usually consist of a metal plunger with a handle on one end and a rubber washer on the other. This fits into a barrel which may be made of either metal or metal and plastic. The barrel is cylindrical and does not taper at the ejecting end. The
plastic part of combination metal and plastic barrel can be removed for cleaning purposes. The nozzle, also plastic is screwed in place by means of a steel screw cap after the material has been aspirated into the syringe.

Kinghorn and Allan (18) and Beagrie (61) use a normal cartridge syringe with a modified needle. The needle is made from a 1.25 mm. bore stainless steel orthodontic tube bent at a suitable angle in a vice and is sharpened at one end to allow its penetration through the rubber stop of the carpule. A chip blower bulb is placed over one end of the carpule. The other end is placed into the mixed rubber base material and with the help of the mixing spatula the impression material is aspirated into the carpule.

Another type of ejection apparatus has been suggested by Sturdevant (112), for use with the syringe type material. This is a capped plastic tube and nozzle. Finger pressure around the tube is used to squeeze the impression material via the nozzle into the tooth preparations.

2. Trays. The trays used for these materials must also conform to the requirements stated on page 73. "Stock" metal trays, either perforated or non perforated may be used, the size depending on the size of the area to be impressed. It is not usual to take full arch impression with the rubber base materials in Crown and Bridgework.

The perforated "stock" tray is not superior to the non perforated type as far as retention of the rubber base materials are concerned as the rubber cements are quite adequate (94). The "stock" trays must be provided with stops etc., as was the case when used with the agars described previously.

Hailey (94) reports that compound for stops and liners is not satisfactory because the material is incompatible with the rubber base. An incomplete setting reaction of the rubber and a softening of the compound is produced where the two materials contact, resulting in little or no retention. He suggests that impression plaster is more satisfactory than compound, as it is compatible, quick to use and dimensionally stable.
Fig. 15.

Plaster Impression over $\frac{1}{8}$" Wax Spacer.
This suggestion is supported by Gruenwald (116) whose technique of obtaining a tray for a bridge is the following. Wax, $\frac{1}{8}$" thick, is placed on the study cast over the abutments and edentulous area only. Separating medium is applied to the study cast around this wax. A plaster impression of this area is taken on the cast and when separated the wax is removed. This may then be used for a rubber base impression tray.

Pearson (60) and Beagrie (61), however advocate compound as a liner in "stock" trays with 3 mm. removed to act as a spacer for the rubber impression material. Morrison (117) also uses compound as a liner in "stock" impression trays. A strip of gauze, single thickness, is cut to fit within the dimensions of the tray. Impression compound is softened, placed in the tray and flamed. The gauze is placed over this compound. The tray is then fitted onto a study cast or into the mouth and a gauze lined "snap" impression obtained, which is removed and allowed to harden. The rubber material may now be mixed and the final impression completed.

McLean (75) suggests another variation in the use of a piece of expanded metal adapted over a wax spacer on the study cast. A compound impression in a "stock" tray is taken and the wax removed. This leaves an excellent means for retaining the rubber base material.

Individual trays may be used. These may be made from alluminium impregnated shellac - perforated (60), from heavy gauge metal mesh, acrylic (either cold or heat cured), or from polystyrene (91) (94) (106). A rubber lined impression tray may be made (118) (119). This tray has stops, an acceptable space between tray and occlusal surfaces of the teeth and is also rigid. A wax separator is placed on the study cast over the area to be impressed. A mix of rubber material is placed over this and, before set, monomer is dripped on. This is then bound together with a sprinkling of polymer. Cold curing acrylic is mixed and placed over this forming an acrylic tray bound to a rubber liner.

Davis (90) uses cold curing acrylic for a tray in the following way. The acrylic is mixed and allowed to remain in the jar. When it has lost its surface tackiness it is moulded with the fingers and
impressed over the area to be restored. This is removed and trimmed while still soft, rechecked and placed in hot water until set. Acrylic burs are used to remove the imprints of the prepared teeth and to leave a 3 mm. space for the impression material. This technique may be used either in the mouth or on a study cast.

3. Copper Bands. These are seamless bands which are supplied in graduated sizes to fit any tooth in the arch. They are used to take single impressions of tooth preparations to make dies. Impressions made with copper bands may be easily electroplated. They are also used where deep proximal cavities are present, since they can be festooned to any desired shape; and also when troublesome gingiva cannot be retracted easily by other means.

They are supplied open at both ends (tube type) or closed at one end (thimble type). A tube type band may have compound or acrylic placed on one end to act as a top or plunger when the impression is being taken. They need the application of a rubber adhesive compound for successful use even though some mechanical retention may be obtained by placing holes or by roughening the inside of the band. The thickness of the band is about 36 gauge.

If the smallest size is not small enough for a preparation, this may be overcome by slitting the band for some of its length and lapping the sides. These may be spot welded. The bands may or may not be annealed depending on the technique or the operators preference. However, once annealed they are softer and more easily distorted.

The bands may be contoured to the gingival margin easily with pliers, crown and collar shears and files, but the adjusted edge must be smoothed with stones and sandpaper discs to protect the gingiva from being lacerated. They are usually supplied about \( \frac{3}{4} \) in length but this may be adjusted if necessary to suit the degree of opening of the mouth or the height of the clinical crown of the tooth being treated.

They should be selected so as not to leave a thin section of impression material between the tooth and band, as such an occurrence leads to distortion and pulling away of the impression material. The occlusal 2/3 of the band may be expanded by using expanding pliers.
to overcome thin areas. The occlusal edges of the band may be cut and bent over to rest on the adjacent teeth to act as stops and seating guides during the impression procedure.

Stainless steel bands may also be used for this type of impression instead of copper bands.
CHAPTER IV

Techniques (cont.)

The clinical techniques available for use with the elastic impression materials are (74): –

1. Injection. This uses a syringe to introduce the soft material into all corners of the cavities before the main mass is inserted in a tray. The injection technique can be used with any of the elastic impression materials. The main limiting factor is the viscosity of the material, which determines the size of the injection aperture.

2. Wash. This enables the material to be used as a thin wash over a trimmed compound, plaster or individually prepared tray. The thickness of the wash can in this way be predetermined and is usually about 3 mm. This technique is used mainly with the rubber base impression materials.

3. Copper Band. This technique is used to take individual impressions of each tooth, and although the band can be perforated to provide mechanical retention, the additional use of an adhesive is adviseable. This technique is also used mainly with the rubber base materials.

A. AGAR-AGAR.

The indirect technique employing reversible hydrocolloid
involves the following phases of procedure: -

(i) Preparation of the agar hydrocolloid,
(ii) Preparation of the teeth and tissues to receive the agar hydrocolloid.
(iii) Injecting the fluid agar into and around the tooth preparations.
(iv) Filling, tempering and placing the tray in the mouth.
(v) Changing the sol agar into a gel.
(vi) Removal of the impression from the mouth, and treatment of the surface of the impression.
(vii) Pouring the stone dies and casts.

The sticks of agar hydrocolloid material are inserted into the small and large syringes. The plungers are inserted into the barrels and the needles are covered with a rubber tip or a threaded metal cap. The syringes are now placed in the boiling water compartment of the conditioner and allowed to remain for 8 - 12 min. 8 min. is the minimum amount of time required in order to liquefy new agar hydrocolloid. When the material is being reused a longer period of time will be required to obtain its complete liquefaction.

As stated in Chapter 1 the manipulation of the material is continued by transferring the syringes from the boiling compartment to the storage compartment which is at a temperature of 145° - 150° F. 5 - 10 min. will be required to reduce the temperature of the agar from 212° F to the storage temperature. The injection of the material into the tooth preparations at higher temperatures may injure the pulp and investing soft tissues of the teeth.

It is not necessary to temper the small syringe at a temperature lower than the storage temperature and it may therefore be left in the storage compartment until required. The reason for this is that the thickness of the agar material as it passes down the nozzle of the small syringe is such that by the time the material has reached the tooth it will be at a temperature which is compatible with the oral tissues. The temperature drop of the agar during this passage is in the nature of 10° to 15° F (84).
The tray material, however, must be tempered. The requirements of tray selection and preparation have been discussed in the preceding Chapter and these must be carried out prior to filling the tray; usually, while the agar is in the storage compartment of the conditioner. When filling the tray, folding or incorporating air bubbles into the material must be avoided. This is done by placing the nozzle of the tube or syringe in the bottom of the tray and squeezing out the necessary amount of material until the tray has been slightly overfilled.

The filled tray is now placed in the tempering bath which is at a temperature of about 115°F. The higher the temperature of this tempering bath, the longer the time required for tempering. Care must be exercised not to keep the tray of material in a lower tempering bath for too long a period of time because the gelation may progress so far that the material becomes too stiff for use. From 5 to 15 min. is required at 115°F whereas no longer than 5 min. is required at 105°F.

Therefore, it is necessary for the dentist to so time himself that his operation at the chair, i.e. preparation of the mouth retraction of the gingiva etc., and the application of the agar to the teeth from the small syringe will consume the number of minutes required for tempering of the tray material at a selected temperature. Once a satisfactory time temperature schedule has been established, it may be followed as routine procedure.

The preparation of the mouth and the retraction of the gingiva have been discussed in the preceding Chapter. The next phase of the technique is the injection of the agar into and around the tooth preparations.

The small syringe is removed from the storage compartment of the conditioner, the covering over the nozzle removed and the first \( \frac{1}{2} \)" or so ejected, and wiped away with the finger. This is done for the purpose of cleaning the needle of any trapped air or water which may have found its way into the syringe.

The tip of the nozzle is next brought into contact with the gingival floor on the distal surface of the most posterior prepared tooth and the agar extruded; the nozzle is then removed occlusally to
cover this part of the preparation and down into the mesial, all the
time keeping the point of the nozzle in contact with tooth structure
and within the mass of agar already extruded. If the material has
been properly liquefied and tempered, it will flow out of the needle
easily and flatten out without forming any folds. At no time should
the needle be withdrawn from the mass of material and reinserted; such
a procedure will cause air bubbles to form within the extruded agar.
When withdrawing the nozzle from the covered preparation, it should be
withdrawn from the occlusal portion of the mass of agar and not from
the proximal aspect.

This system is followed for each preparation going from the most
posterior to the most anterior preparation.

This initial application of the agar to the tooth preparations
must be carried out fairly rapidly so as not to allow the material to
cool to the point of gelation. Should gelation occur, the agar in the
tray will not adhere to that around the tooth preparation when the
impression is taken; in addition, the gelled agar covering the teeth
cannot be compressed against the teeth to secure all the details of
the cavity preparation. Also if the first application of agar is
contaminated with saliva etc., it is possible that no union will occur
between it and the agar in the tray (88).

While the agar is being applied around the tooth preparations,
the assistant removes the filled tray from the tempering bath, attaches
the water tubing to the tray handle, and with a sharp knife shaves off
the top layer of agar which was exposed to the water in the conditioner.
This gives a fresh surface of agar which is undiluted and which will
adhere to the soft agar covering the tooth preparations.

The tray is now positioned in the mouth being guided by the stops
and held steadily without any further vertical or lateral movements.
Water is now permitted to pass through the rubber tubing and circulate
through the tray, cooling the material to the point of gelation. The
controversy whether to use iced water or tap water at 70°F has been
discussed previously.

The impression is held in position for 2 - 3 min. after obvious
gelation has occurred. The total time of holding the impression varies from 5 min. upward, depending on the product and the volume of agar in the tray.

The removal of the tray impression is one of the most critical phases of this technique. The tray should not be removed using its handles as a lever; instead the fingers should be placed over the rim of the tray and the impression should be dislodged with a sharp, straight pull away from the teeth. At no time should the impression be teased out or removed with a rocking motion as distortion or fracture may result. If the tray and impression material separate in the removal of the impression, it should be discarded.

Upon its removal the impression is examined for accuracy of detail and for the presence of any bubbles or signs of dragging or tearing. An opposing arch impression and necessary records for mounting on articulators etc., are obtained.

If the impression of the prepared teeth is satisfactory it is fixed if necessary, air dried but not desiccated and dies or cast obtained. This latter procedure will be described in the next Chapter.

The above technique has been described by many authors (6) (29) (39) (74) (84) (97) (100) (103) (105) (120) (121) (122), and is the general one used for the agar elastic impression materials.

Lindley (108) reports a slight variation to the general technique in that a brush may be used to apply the agar hydrocolloid to the tooth preparations, and that a small towel may be used to remove any excess water from the surface of the agar in the tray after it has been tempered. This is done by tamping the material on the towel.

A combination reversible and irreversible hydrocolloid technique may be used. This involves the use of a reversible agar for the prepared teeth with the irreversible hydrocolloid in the tray. The union of these two materials is strictly mechanical, and in order to strengthen this union Hollenback, as reported by Skinner and Hoblit (36), advocates that the reversible hydrocolloid be injected into the tooth preparation in excess, and then a small, specially formed piece of
Fig. 16.

Lister's Method of Recording Pinholes.
perforated metal is laid over the agar. This unites the two materials firmly together mechanically. Although accurate results have been obtained it seems that unnecessary complications are introduced by this technique.

Agar is also used in cases which have pin holes in their preparations. Pruden (111) uses a 25 gauge, cartridge needle as a nozzle for the syringe and a slightly more fluid agar. This enables the injection of the agar to be started at the bottom and the pin hole filled as the syringe is withdrawn. This is continued in an orderly manner as rapidly as possible, care being taken not to overfill the pin holes. As the material is not adhesive, the weight of excess bulk may allow gravity to drag the agar out of preparations in the upper arch. Any excess agar may be quickly wiped off with the finger. Another syringe with a larger nozzle is used to inject around the gingiva thus locking the material in the embrasures. The impression is completed in the usual manner, except that cooling is allowed to continue for a slightly longer period of time to gell the agar in the pin holes.

Another method of recording pin holes using agar hydrocolloid has been proposed by Lister (123). Lengths of iridio–platinum wire which fit the pin holes are inserted and cut $\frac{1}{4}$" from the incisal edge. Their free ends are sharpened and a thin flat piece of corking is speared onto them and made fast with sticky wax. The agar material may now be easily injected around the pins (which can be held firm with a finger on the corking), and the impression completed in the usual manner. The advantages of this system are:

(i) The operator can easily ascertain the path of withdrawal from three straight parallel pins.
(ii) There is less chance of lateral stresses being produced on the pins during the removal of the impression.
(iii) The flat piece of cork produces better retention of the pins in the agar and the pins will not tear out.

Plastic points may also be used to record pin holes in conjunction with agar hydrocolloid. These, however, may be too big for pin holes in preparations of anterior teeth. Makinson (124) suggests that
a 0.5 mm. diameter platinum-irridium wire should be placed in the hole, the free end having been bent for retention in the agar, and kept in place with a minute amount of wax. The impression is taken in the normal way. Tubes of an internal diameter of 0.5 mm. are slipped over the pins and the casting obtained. This results in an accurate reproduction of the pin holes.

When an impression of a post canal preparation is required, a short miniature fissure type bur may be used in combination with the agar hydrocolloid.

Larson (86) reports that the agar hydrocolloid technique may be used in almost all cases some being a little more difficult than others. For example,

(i) Copious and ropy saliva, which is always a problem, can be overcome by premedication with 50 to 100 mg. of Banthine.

(ii) The impression involving a full crown preparation on a lower third molar with a great deal of loose tissue distally and closely ascending ramus is a difficult operation. This may be overcome by taking a copper band impression with compound this being left in place and an agar impression completed.

(iii) The impression of an anterior three quarter preparation with close approximation with the adjacent teeth and a wide embrasure at the gingiva is difficult. A small interproximal space with a larger mass of material at the gingiva is present resulting in the inevitable tearing of the thin wall of material. This may be overcome by injecting the lingual of the preparation, wiping away any agar which appears on the labial, coating the interproximal agar with a separating agent, and injecting the labial aspect. The separating agent prevents the two sections from fusing. On withdrawal they come away cleanly and snap back together. However care must be taken when pouring the cast.

B. ALGINATE.

The alginate impression materials are not used to the same degree nor with the same confidence as the agar impression materials in Crown
and Bridgework. In other parts of Dentistry the alginates are replacing the agars almost completely e.g., the newer alginates are quite accurate enough to obtain excellent impressions for the construction of metal partial dentures.

In Crown and Bridgework, however, the impression material must be directed into areas which are not only very critical, but are also very small. With the hydrocolloids this can only be done properly by an injection technique. As the gelling time of an alginate is very short and cannot be altered to the degree that is possible with an agar, difficulties are encountered in obtaining an impression which has excellent qualities and in which both tray and syringe material have united properly (125). This failure of proper union results in distortion and inaccuracies.

The addition of a chemical retarder can be effected successfully only by the manufacturer, and up to the present time this has not been done. Even though ice water is used and all equipment and materials may be placed in a refrigerator before the impression is taken (the mouth may also be rinsed with cool, not iced, water) the set can only be delayed long enough for 2 - 3 cavities to be injected. This is because the amount of material injected is small enough for the normal mouth temperature to overcome the cooling effect attempted.

There are certain points to be observed when using alginate with an injection technique (125).

(i) The material with the most suitable viscosity should be selected and it should exhibit a gelation time of 6 - 8 min. when ice water is used for mixing.

(ii) The equipment must be cooled in a refrigerator. If unit packs are used these may also be cooled, but large cans of powder cannot sustain this treatment.

(iii) The instructions of the manufacturer must be followed carefully.

(iv) Once the material is mixed speed is important. The tray should be filled and the preparations injected as rapidly as possible with the tray being placed immediately before any gelling can occur.
The following technique has been suggested by Peiffer and Jeffries (56), and it can be seen that it resembles the agar technique very closely. The mouth preparation, gingival retraction etc., is completed as has been discussed previously.

An additional 6 c.c. to the specified amount of ice water is mixed with the specified amount of powder in the precooled bowl, the timer having been set for seven minutes from the commencement of mixing. The mixing is performed vigorously and is completed at the end of one minute. The manipulation of the alginites has been discussed in Chapter 1. A small cement spatula is used to fill the syringe with 1.5 to 2.0 c.c. of impression material. This material is ejected into and around the prepared teeth by the dentist while the assistant fills the impression tray.

In ejecting the impression material, the preparation first should be filled at the bottom of gingival aspect so as to force out any retained air and prevent bubble formation. The impression tray is next vibrated into place. Approximately three minutes should have elapsed up to this point leaving four minutes for the alginate to gel.

When the required time has elapsed, the impression is removed, inspected, washed and fixed if necessary. This technique has also been suggested by Pfeiffer in another publication (114), by Hampson (126), and by Hohlt (39) who aspirates the alginate into the syringe instead of loading it with a spatula. Fusayama (127) also uses this technique the slight difference being that the syringe is loaded through a window in the side of the barrel so saving a small amount of time. He also uses a tray with a loose joint to the handle in order to prevent strain on the impression when being removed.

Various other techniques of impression procedures involving alginate have been recorded. Feinberg (128) uses a combined plaster and alginate impression, in which impression plaster is used in the areas of tooth preparations - so that the dies can be held more firmly - and alginate is used for the remainder of the arch. The part of the tray covering the prepared area is cut out and an alginate impression
is taken of the whole arch. The alginate is removed from the prepared area and transfer copings are placed on the tooth preparations.

This modified alginate impression is replaced in the mouth and a thin mix of quick setting plaster is inserted so as to fill the area around and over the copings. The impression plaster may be compressed slightly with a piece of wax and is held until set, and the whole record removed.

Another variation of the plaster and alginate technique has been suggested by Brotman (129). Single impressions are obtained, dies made and transfer copings made and placed on the tooth preparations in the mouth. A rim lock tray is selected and the prepared area marked on the tray. Two mixes are made simultaneously; the dentist mixing the alginate while the assistant mixes the plaster. The plaster is placed in the tray over the prepared area and the remainder of the full arch impression tray is filled with alginate; the tray is positioned and both materials allowed to set together. When the tray is removed the copings are in the plaster, the dies are inserted and the remaining part of the impression is cast.

Saizar (130) suggests an alginate impression confined in alginate. A simple alginate impression is obtained. 3 mm. of alginate is scooped out around the preparations and some retentive areas included. A small amount of fresh alginate is prepared and placed in this scooped out area. The whole impression is replaced and vibrated slightly to eliminate the elasticity developed in the alginate of the base. This is then held immobile and without pressure. When the impression is removed the ridges are trimmed and a casting is made.

The previous combination impressions seem to be subject to the introduction of errors in that either more materials are being used or the impressions are being placed and replaced too often. The simpler the impression technique with the less number of instruments and materials being used the more likelihood it has of succeeding.

C. RUBBER BASE.

The rubber base materials are quite versatile and either may be
used in the techniques to be described.

**Impressions with Copper Bands.**

The types of copper bands available have been described in the previous Chapter. A band of suitable size is selected and contoured and shaped to fit the tooth a little loosely. This band is usually slightly larger than the one selected for a compound impression of the same tooth, so as to allow for the elasticity of the rubber to be utilized to its fullest advantage during removal over the height of contour and undercuts of the outer surface of the tooth (17) (96) (118) (131).

The contour and shape of the band depend on the type of tooth preparation.

(i) **Full crown.** The band is trimmed to cover the whole of the preparation and to extend just past the gingival margin.

(ii) **M.O.D.** The band may cover the whole of the tooth if it fits loosely and if the tooth does not have excessive undercuts buccally and lingually. If these undercut areas are present either the band is trimmed so as not to extend to them, or they may be eliminated with a suitable material and a normal band impression obtained. This also applies to other types of preparations such as three quarter, pinledge, McBoyle etc.

(iii) **M.O. or D. O.** The band is trimmed so that, although it covers most of the crown of the tooth, it is not forced past the contact area of the unprepared proximal surface.

The actual impression taking consumes a small part of the time needed for this technique, most of the time being used in properly preparing the band (132). The copper band is now examined and it should allow for \( \frac{1}{2} \) mm. of space between the band and the subgingival margination of the preparation. It must be festooned is such a manner as to extend subgingivally to include all parts of the tooth which have been prepared. The band may be crimped in toward the gingival margin to assist in the retention of the rubber base material as well as to deflect the gingival tissues during the impression procedure (132) (133).
Some provision for removal of the band may be made by drilling holes just below the free end of the band and passing wire from labial to lingual. This wire may be steadied with compound and thus a type of handle is formed. The compound itself may be used as a handle. The outer surface of the band may be reinforced with compound on the buccal and lingual surfaces and over the occlusal surface keeping 3 mm. above the tooth if an open end band is being used. This reinforcement is particularly necessary if the band had been annealed. The excess compound may be placed over the occlusal surfaces of the adjacent teeth to act as stops during the seating of the tray (96) (133).

The copper band technique should not be used on approximating preparations as there is seldom enough room for two bands to be placed accurately in such cases (94) (131).

With the band thus prepared, holes are made on its labial and lingual surfaces, it is washed and dried and the inner surface coated with a rubber base adhesive. A single mix of impression material is usually used when using the copper band technique, although a two mix technique, employing a syringe, produces excellent results. The material chosen for a single mix technique should be of the "regular" or "heavy" type. A "syringe" type material should not be used (132).

The string is removed from the gingival crevice (where it had been placed just before the holes were made in the band for retention of the impression material), the mouth rinsed if necessary and the preparations dried. The impression material is mixed and using a small spatula, plastic or explorer the preparation is coated with the material. This is quickly worked into all line angles and into the gingival crevice. The copper band is now filled and inserted over the preparation, being guided to the stops. The copper band is held gently in position until the material has set at which time the impression is removed and examined.

A full arch impression is now taken into which the die or dies made from the copper band impression can be seated for the construction of a working cast. Maxillo-mandibular records are also taken at this time. The full arch impression may be taken while the copper bands are
still in place over the preparations and everything removed from the mouth together. If this full arch impression is taken with rubber base material then it is necessary to apply the rubber adhesive on the outside of the bands as well as the inside (94). Alginate may also be used or even plaster (131).

Silver (134) describes an acrylic copper band tray impression technique. Annealed copper bands are contoured and festooned to fit each of the prepared teeth in the usual way. The occlusal end of the bands are notched. Self curing acrylic resin is mixed in a dappen dish, and when the "dough" stage is reached, it is placed over the occlusal ends of the bands and on the edentulous areas. The resin is allowed to harden in the mouth. The copper bands, which are held together in one piece by the resin, are removed.

Rubber base impression material is mixed and inserted in the copper bands and on the ridge areas. The filled acrylic copper band tray is placed in position over the teeth and held lightly in position until the impression material has set. This is not removed. A full arch impression is taken over this acrylic copper band tray. This allows correct relation of the dies to the adjacent teeth.

**Syringe and Tray Technique.**

This technique involves the use of two pastes of different viscosity, one being used for the syringe, a "light bodied" paste, and one for the tray, "a heavy bodied paste". The superiority of the double mix technique has been mentioned previously and may be used in most impression procedures in Crown and Bridgework.

The advantages of this technique over the copper band technique have been stated by Kinghorn and Allan (18) thus:

(i) A greater bulk of material than can be contained in a copper band is free to spring past the bulbous contours of the tooth and to recover its form.

(ii) With a model which is initially cast in one piece there is no problem of location of dies.

(iii) Multiple preparations can be dealt with in one impression with little extra effort.
The phases of this technique are as follows:

(i) Preparation of the material and equipment.
(ii) Preparation of the mouth and the retraction of the gingiva.
(iii) Loading of the syringe and injecting into the mouth.
(iv) Filling the tray and positioning in the mouth.
(v) Holding the tray in the mouth for the required time.
(vi) Removing the tray and inspecting the impression.
(vii) Obtaining the dies and casts.

Phases (i) and (ii) have been described previously and during which a rubber adhesive material is applied to the inner surface of the tray and allowed to dry. In phase (iii) both the syringe and tray materials are mixed simultaneously. The tray is filled with the heavy bodied paste using the spatula. The syringe may be filled by placing the material in a dappen dish and aspirating it up the barrel or by making a paper funnel into which the syringe material is placed and squeezed into the syringe (132).

The syringe material is injected in a similar way as was done with the agar hydrocolloid, the difference being that slightly more time is available with the rubber base materials. When the tooth preparations are covered the tray is inserted and seated. The cotton rolls may or may not be removed before the tray is inserted. It may be adviseable to leave a cotton roll opposite the orifice of a salivary gland duct. This cotton roll will be pushed out of the way as the tray is being seated and will help keep the field dry.

The tray is held thus for the time specified (usually 10 min.) at the end of which time the set of the material should be tested. The curing time varies with the temperature of the room; a high room temperature shortening the working time. This may be offset by the addition of a drop of retarder solution. During this period the tray material will also have bonded with the syringe material.

The impression may now be removed using a quick action supporting the entire tray and not using the handle of the tray as a lever. The impression is examined and if satisfactory the cast may be poured. If deficient in any place the impression should not be relined but should
be discarded and a new one obtained (135).

The above technique has been suggested by various authors (17) (18) (68) (112) (132) (135).

Myers (68) suggests a tray technique without the use of a syringe. He reports that one rubber base product passes through a non sticky stage and can be moulded similarly to impression compound. Small cones are placed in the cavities or tooth preparations, the tray loaded and inserted in the usual manner.

McLean (75) suggests a syringe and tray technique with a variation in the catalyst/base ratio when silicone materials are used. 25% less catalyst than the specified amount is suggested for the syringe mix and is spatulated for 1 min. While this is being injected the assistant adds an extra one half the original amount of catalyst to the already mixed material. This is spatulated for a further 30 secs. The tray is loaded and seated in the mouth. The injected mix is united with the booster mix in the tray and the polymerization of the total mass is accelerated.

Impressions of pin hole preparations may also be obtained with the rubber base materials. Allred (136) suggests the following technique. Old 700 tapering fissure contra angle burs are cut where the shaft starts to taper. The burs are placed in the pin holes and a single layer of pink sheet wax is adapted labially and lingually over the area to be impressed and also over half of the neighbouring teeth. A compound impression is now taken, the wax preventing displacement of the burs and allowing $\frac{1}{8}$" thickness to act as a spacer. The teeth at either end of the arch are used as stops. The wax is now discarded. The impression and bur heads are dried and coated with an adhesive. The impression material is mixed, each bur head is coated and inserted into a pin hole. The usual injection and tray procedure is now completed.

Willmott (137) advocates the following technique. An ordinary pin is obtained, and cut so that when placed in the preparation, the head is 2 – 3 mm. above the pin hole. The cut end is flattened or notched, softened compound is placed around it and an impression of
the pin hole obtained. A suitably sized tray is filled with softened compound and seated over the prepared area — any gross undercuts having been blanked out. Two teeth on each side of the space are included in this impression.

The impression is removed and it will be found that the pins are held in the tray compound. The remaining undercuts are trimmed from the tray compound, an adhesive solution applied and allowed to dry. The rubber impression material may be mixed and the impression taken in the usual way.

CLEANING THE SYRINGE.

A clean syringe is essential to the successful use of the mercaptan and the silicone impression materials (138). To clean the syringe after use, the material remaining in the syringe must be completely set. This set may be hastened by placing the syringe in warm water not exceeding 120°F for 1 - 2 min. The syringe is disassembled. If the inside of the plastic sleeve (if such a syringe is used) had previously been lightly lubricated, the remaining material may be withdrawn in one piece.

The inside of the barrel or plastic sleeve may be cleaned by passing a slightly lubricated brush through several times. Caution must be taken not to use an excess of lubricant as it may interfere with the working qualities of the impression material. All metal parts of the syringe may be sterilized by any conventional method, the plastic sleeve and point being placed in a cold disinfectant solution.
CHAPTER V

Dies and Casts

The indirect technique depends, not only on the subject matter discussed up to this point, but also on the exactness of the dies used and their resistance to deformation during the fabrication of the appliance (139). Dental stone, plaster, casting investment, amalgam, silicophosphate cement and electrodeposited silver or copper are materials which may be used to make dies from dental impressions. No one cast or die material is ideal in all qualities or compatible with all impression materials (14). The cast or die material which is selected for a case depends on the impression material used, the purpose for which the cast or die is to be used, the time factor involved and the materials which will be manipulated on the cast or die.

DESIRABLE QUALITIES OF DIE MATERIALS (14).
1. Cast and die materials are required to reproduce an impression accurately and to remain dimensionally stable under normal conditions of use and storage.
2. Effects of temperature variations on the materials should be at a minimum.
3. They should reproduce fine detail satisfactorily and have a smooth, hard surface.
4. They should be strong and durable so as to withstand manipulation procedures without surface abrasions or cast fracturing.
5. They should be of a contrasting colour to the materials used in conjunction with them.
6. They should adapt themselves easily to the impression and not react with the impression surface.
7. An excessive time should not be required before the cast or die is ready for use.

The structure and properties of the die and cast materials, and the effect of storage time and centrifuging, oil immersion, water immersion, crushing strength etc., will not be discussed; only the methods of obtaining casts and dies from elastic impression materials will be reviewed.

The materials used for making dies and casts from elastic impressions are restricted to those which can be poured or packed without pressure (28) i.e.

1. Plaster and stone
2. Metal Electrodeposition.

PLASTER AND STONE.

All types of elastic impression materials can have a gypsum type material poured into them. Stone casts are stronger and resist abrasion better than plaster casts and are used whenever a restoration or appliance is to be made on the cast. Plaster may be used for study casts which are for record purposes only. The improved dental stones currently available make an excellent cast or die and will readily reproduce the fine detail of a dental impression (14). They have most of the desirable qualities listed above. Procedures involving the bending, adapting, or finishing of metals, however, can be accomplished only to a limited extent.

The manufacturer's directions should be followed carefully in the manipulation of these materials. Optimum results are obtained when care
is directed to measuring the correct W/P ratio, spatulating for the specified time, allowing 45 - 60 min. to pass before removing from the impression, and waiting approximately 24 hr. if the full strength of the cast is desired (14).

Although it is possible to obtain a good mix of stone by using the usual methods of spatulation, stone mixed in a vacuum has given improved results (84). Sifting stone into a bowl gives less porosity than when dumped; a flexible rubber bowl results in slightly better spatulation than a glass bowl and mechanical spatulation gives the most consistent results (33) (140).

All excess potassium sulphate or water should be removed from the impression (being careful not to dehydrate it if the hydrocolloids are used) before pouring the stone (32) (39) (40) (85) (121). There is less chance of trapping air in the cast if the stone is vibrated mildly into the impression (32) (39) (40) (43). Stone added in large quantities accompanied by excessive vibration has a tendency to entrap air bubbles. The impression should be filled by placing small increments of stone in one section of the impression and allowing the stone to flow into other parts from this initial point of application. Immersing the poured model in a 2% potassium sulphate solution for 10 - 15 mins. will improve it especially when the impression material is one of the hydrocolloids (33) (84) (88).

It should be stressed again that only the best quality stone should be used. The best W/P ratio has been found to be 24 - 25 c.c. water to 100 Gm. powder (39) (40) (91). Thompson (37) and Kahn (85) (105) suggest that excess moisture be removed from the freshly mixed stone by a blotting action on a clean towel. It seems that this is not necessary if the proper W/P ratio is used and that inconsistencies will result since the amount of moisture removed by blotting cannot be standardised.

METHODS OF MAKING DIES AND CASTS.

There are several methods available in making dies and casts when the elastic impression materials are used in conjunction with stone.
1. Two separate impressions are required. Individual dies are poured into the first impression which are subsequently used for making and finishing the wax patterns for the individual teeth. A solid master model is poured into the second impression which is used to determine the occlusal and contact points and on which the bridge is completed (84). This method is used with the hydrocolloid impression materials since two pours of stone can be made in the rubber base materials which almost equal accuracy, the difference not being of significance clinically.

2. This method employs one master impression and has been suggested by various authors (29) (84) (98) (103) (116) (121) (122) (126). Stone dies are poured into the impressions of the prepared teeth and allowed to set in an atmosphere of 100% humidity or in 2% potassium sulphate solution (98) (103) (121) when the hydrocolloids are used, or in a cool, dry place when the rubber base materials are used. Hart (121) states that the dies should be stored in the potassium sulphate solution for between 30 and 60 mins. Less than 30 min. produced a rough or chalky stone surface, while more than 60 mins. produced a slight dissolution of the stone. In pouring the individual dies, either an excess of stone is heaped up in the shape of a cone approximately \( \frac{1}{4} \) inch in height, or dowel pins may be placed. It is advisable that dowel pins are positioned in a direction along the long axis of the teeth and it is usually safer to keep them in such a position by sticking them to supports (pins, tooth-picks etc) placed Bucco-lingually across the margins of the impression, or by using a dowel pin parallelator as devised by Mann (28). Care should also be taken to ensure that the serrated ends of the dowel pins are covered completely with this first pour of stone. At the end of 30 min., the individual dies have set, and are removed from the impression. They are now trimmed, the root ends tapered, lubricated and replaced in their respective positions in the master impression. A new mix of stone is prepared and poured to fill the remaining part of the impression. This produces a master model with removeable dies which can be replaced accurately into their sockets.
Clappison (98) and Bignell (103) suggest that in this method when dies of adjoining teeth are necessary, it is better to have two impressions and pour alternate dies in separate impressions.

3. A third method similar to the second has been suggested (29) (37) (84) (121) (122). The individual dies are poured and allowed to set as was described in the second method. The dies are carefully removed from the impression, trimmed and laid aside. A new mix of stone is then poured into the entire impression giving a solid master model. The individual dies are used for the final marginal finish of the wax patterns; the master model is used for the initial application of wax, for determining occlusal and proximal contacts, and for completing the bridge.

4. This method employs one impression in which a master model is made with individual removable dies, the dies being poured with a separate mix of stone to the base. The dies are separated either by previously positioned metal strips (39) (84) (132) (141) (142), or by cutting with a fine saw blade (4) (18) (90) (100) (105) (113):

(i) Metal strip technique. Stainless steel strips 0.001 or 0.002 inch in thickness are cut; two being cut for each of the prepared teeth. Each strip should be trimmed to follow, but not quite touch, the buccal, lingual and gingival contour of the impression. It should be emphasized that the strips do not touch the impression at any place. Where a gingival margin is adjacent to an edentulous area, the strip is positioned over the edentulous region about 1 - 2 mm. away from the impression of the gingival margin. 1 mm. of wax is flowed upon the buccal and lingual regions of the impression. The strips are heated in an open flame, being held with tweezers, and are placed in position in the impression so that they are held in the wax previously placed and that they converge slightly apically. Wax is used to seal off any openings between the gingival edges of the outside strips and the impression.

The spaces between the strips are poured with a high strength,
low setting expansion stone, stopping approximately 1 mm. short of the
top edge of the strips. The dowel pins are inserted so that they are
approximately parralell to the axis of the teeth and to each other.
This may be done by hand or by the use of a paralleling instrument.
If hydrocolloid is used the stone is allowed to set in a humidor for
about 30 mins.

Separating medium is applied to the hardened stone and the
remainder of the impression is poured. When the second pour of stone
has set the impression is removed and the two sections of the cast are
separated, by tapping the end of each dowel pin. The thin strips are
removed and the individual dies are separated easily.

(ii) Cut model technique. This technique is similar to the
Metal Strip Technique, except that the strips are not used at all.
When the base mix of stone has hardened the individual dies are separated
by cutting the perfectly dried tooth portion with a fine jeweller's
saw. This may be done, either before separating the tooth portion where
the cut is made from the gingival margins to the model base, or after
the tooth portion has been separated en masse from the base portion
where the cut is made from the model base to within 1 mm. of the gingival
margins and the dies completely separated by snapping the stone with
finger pressure. The use of different coloured stones for the tooth
portion and the base portion facilitates this technique.

The individual dies may now be trimmed and the bridge or crown
etc. completed. Kahn (105) lists the advantages of this technique
as follows: –

(i) There are no fuzzy surfaces on the teeth, no familiar scratches,
cracks or missing corners.

(ii) The die is accurately seated in the correct relationship to the
adjacent teeth.

(iii) The proximal surfaces are complete and it is not necessary to
scrape them.

(iv) Precise fitting contact points are developed easily.

(v) Occlusal adjustment is kept to a minimum because the cast can
be articulated.
5. This method also uses one master impression. The complete impression is poured in stone and seated on a keyed base. Vertical cuts are made through the model when it is dry to within 1 mm. of the gingival wall of the preparations. The various sections are then wedged apart carefully so as not to ruin the margins of the abutment dies and so that areas are left which come into contact when the sections are replaced in the keyed base. This stabilizes the various sections and makes it possible to establish the correct contact relationships. Thus a series of model sections with individual dies is obtained which, when assembled, constitute the master model.

This method has been suggested by various authors (39) (56) (60) (74) (84) (88) (141).

The types of keyed bases vary and may be any of the following, the choice depending on the operator and the requirements of the case in question. They may be made of plaster, plastic, or metal.

(i) Plaster matrix.
(ii) Typodon Base.
(iii) Key Bar Base.
(iv) An articulating Key.

Perdigon (40) uses this fifth method also with a slight difference that the cast is duplicated before the dies are cut. The master model is then used to make the dies and the duplicate model is used for contacts and articulation. This introduces other sources of error in the duplicating process.

A cast obtained with the elastic impression materials is much easier to pour if it is boxed. Davis (143) suggests a technique for boxing alginites and agars and which may also be used with the rubber base impression materials. A narrow strip of wax is placed around the outside of the impression tray before the impression is made. The impression is taken. The thin flash of excess impression material that flows over the beading is easily removed with a sharp knife and the boxing strip of wax can be luted to the beading easily.
The various techniques described above can all be used satisfactorily in the construction of dies and casts from the elastic impression materials. Hohlt and Phillips (141) studied the accuracy of the contact areas of the dies and casts produced by these techniques and found that only when the fractured dies were not trimmed properly or when the metal strips were too thick or pushed too far into the impression did inaccuracies result.

METAL ELECTRODEPOSITION.

Dies may also be made by electrodepositing metals onto the surface of the impression. When a suitable amount of metal has been deposited the dies may be completed by pouring stone or low fusing metal alloy and thus completing the root portion. Copper depositing on hydrocolloids has been described in the literature (144) (145) (146, i, ii, iii), but in the light of the evidence on the dimensional stability properties etc. suggested in Chapter 1, it does not seem possible that an accurate die using a metal electrodepositing technique can be obtained with the hydrocolloids.

Thiokols and silicones are, however, stable enough for the electrodepositing procedure. On reviewing the literature Phillips and Schnell (147) in 1958 concluded that further research was required before the status of plating techniques for Thiokols and silicones could be established. However Tylman and Tylman (138) suggest that Thiokols are more easily silverplated while silicones may be either copper or silver-plated. The copper plating of silicones is also supported by Goldblatt (148).

Other authors (14) (93) (118) (134) (135) (149) (150) also suggest the silverplating of the rubber base impression materials for the production of accurate and strong dies.

ELECTROLYTES AND NON ELECTROLYTES.

For reasons of completeness and clarity, a brief discussion on
the chemistry of electrodeposition is necessary. When a substance is in solution, such as a solid dissolved in a liquid, it may be either dissociated into ions or remain nondissociated as molecules. A solid composed of distinct molecules is best dissolved by a liquid whose intermolecular forces are of approximately the same strength and nature as those existing in the solid. For example, solid sulphur, containing molecules of $S_2$, is readily dissolved by liquid $CS_2$. Naphthalene, $C_{10}H_8$, is readily dissolved by hexane, $C_6H_{14}$. Water is a very poor solvent for these substances because the field of force around a water molecule is different from the fields of force surrounding the molecules just mentioned. However, the process of dissociation occurs readily with the solution of acids, bases and salts in water. Such substances have their molecules dissociated into the component atoms, which, in solution, become electrically charged atoms or groups of atoms known as ions (20).

A molecule such as water is called an electric dipole and will orient itself in an electric field because it is relatively positive in one part and negative in another. Fig. 17.

![Diagram of water molecule as an electric dipole](image)

Fig. 17.

It is surrounded by an electrostatic field, very different in nature from the field of force surrounding a sulphur molecule (151). Water is, however, a good solvent for a substance like sugar, whose molecules contain a number of OH groups, each an electric dipole similar to the water dipole. Solids of the salt type are similarly dissolved. When the water molecule reaches the surface of a salt crystal, e.g. KCl, it tends to orient with its negative part towards the positive potassium atom and its positive part towards the negative chlorine atom. This weakens the force between the charged atoms of the crystal so that, if it is not too strong, the charged atoms may be detached from the crystal and wander off into solution each surrounded
by an envelope of oriented water molecules. These charged atoms in solution are but weakly attracted to each other and can move about in the solution almost independently (151). An electric current facilitates this movement.

All dissociated substances in solution will conduct an electric current and are known as electrolytes. Those conducting very well, the strong acids and alkalis and most salts, are called strong electrolytes. An electrolyte, therefore, is a solute, which, when dissolved, can give rise to electrolysis, and electrolysis is the conduction of electricity by a solution (20). The presence of these ions and the process of electrolysis are important in the electroplating process applied to dental operations as well as to industrial plating.

(The difference between electroplating in dentistry and commercial electroplating as described by Carman (152), is that the dental die uses the first layer deposited as the outer layer and is therefore the important one, whereas the final layer is more important commercially. Also dental dies have complicated shapes as well as a greater variety of shapes as compared to commercial products which make dental electroplating more difficult).

When an electric field is superimposed on an electrolyte, the atoms or ions present in this solution are attracted toward the electrode of opposite charge. The movement of ions through the solution is not rapid, but rather it occurs by a different process. The ions migrate only a few centimeters per hour, the rate depending upon the induced voltage, distance between electrodes, temperature of electrolyte and its concentration (20). This migration of the ions through the solution, therefore, constitutes the passage of the current in solution.

Positive ions or cations are atoms that have lost one or more electrons during dissociation and are drawn to the negative pole or cathode by electrostatic attraction. Negative ions have gained one or more electrons and move toward the positive anode.

ELECTROPLATING IMPRESSIONS.

Since the electron flow in solution during the electroplating
process is from the negative pole to the positive pole, the electrons are supplied from the negative pole and are discharged at the positive anode. The positive cations are attracted to the negative cathode.

During the process of solution in a copperplating bath, the copper sulphate (CuSO₄) is ionized to Cu⁺⁺ and SO₄²⁻ ions, and the water is ionized to H⁺ and OH⁻ ions. The SO₄²⁻ and OH⁻ ions are attracted to the positive anode and the Cu⁺⁺ and H⁺ ions are attracted to the negative cathode. At the anode, because of the relative positions of the SO₄²⁻ and OH⁻ ions in the electro-chemical series, the OH⁻ are discharged more easily, the reaction being (153):

\[ 20\text{OH}^- = \text{H}_2\text{O} + 0 + 2e^- \]

\[ 20 \rightarrow \text{O}_2 \uparrow \]

Similarly the copper ions are deposited rather than the hydrogen ions at the cathode, and the cathode is coated with metallic copper. This is because the Cu⁺⁺ ion gains 2e according to the equation.

\[ \text{Cu}^{++} + 2e^- \rightarrow \text{Cu}^0 \]

If an impression is placed at such a cathode it would therefore be deposited with metallic copper. Such an electrolyte would lose its ability to copper plate because of the depletion of the Cu⁺⁺ ions from the solution. If the anode is made of copper however, the reaction at this electrode is changed. The copper atoms of the anode give up two electrons (2e) and become Cu⁺⁺ ions. Again this is because of the relative position of Cu⁺⁺ and OH⁻ in the electrochemical series (153). The reaction at the cathode remains unchanged.

The metallic copper of the anode, therefore, regenerates the solution as the plating process occurs.

Neutral or undissociated molecules do not move under the influence of an electric field. Hence, a nondissociated substance such as glucose will act only to inhibit the migration of the copper or sulphate ions.
Similar reactions to those described above would occur in the silverplating process.

EQUIPMENT FOR SILVERPLATING.

The essential equipment for the electroplating of impressions to form indirect dies for inlay, crown, or bridge restorations is a source of direct electric current and an electrolyte. The electric current may be supplied by storage batteries of the dry cell type, with a small variable resistance and an ammeter to indicate the energy in the system. A transformer and rectifier may also be used to reduce the voltage of the domestic supply and convert the AC current to DC current which is needed for electroplating the impression. The low voltage direct current passes through a variable resistor, which is used to regulate the current and modify the rate at which metal is deposited (14).

The equipment needed for silver electroplating is the following (138):

(i) A pure silver anode, which is of a size and weight suitable to the size, shape and volume of the liquid in the tank.
(ii) An ammeter which registers in milliamperes within a range of 0 – 500 milliamperes.
(iii) A 1 – 2 quart plating tank of glass, hand rubber, or some type of plastic which will not react to the cyanide solution. The container should have a well fitting cover to prevent the evaporation of the solution.
(iv) A cathode suspension holder of the single or multiple type and a stainless steel anode holder.
(v) Silver cyanide solution. This may be obtained in concentrated form, which is then diluted with distilled water in the specified proportions. Such a solution is allowed to stand for at least one day before it is used. The solution may be made up by the dentist, the following formula, as recommended by Hudson (135) may be used.
silver cyanide 4 oz.
potassium cyanide 7 1/2 oz.
potassium carbonate 6 oz.
distilled water 1 gal.

Peyton et al (14) suggests a similar formula. Distilled water may be added to restore the proper level of the solution from time to time as some of it is lost due to evaporation. If much plating is done, it may be necessary to filter the solution to remove debris and impurities. Since cyanide compounds are extremely poisonous, especially if brought in contact with acid, the silver-plating bath should be kept well away from a copperplating bath if both are in the same room. Hands should be washed thoroughly if contact with the plating solution occurs. The cyanide solution should not be heated as there is danger from the fumes which are formed. It should be maintained at room temperature and if it has been thoroughly mixed, continuous agitation during the plating process is not necessary (138).

(vi) A bottle of metallizing powder of pure silver.
(vii) A bottle of masking lacquer.
(viii) Fine brushes.

SILVERPLATING TECHNIQUE.

It is necessary to clean an impression before electroplating it, in order to get rid of any blood, saliva, or any loose tooth particles present. This may be done with running water and a brush. 50% mixture of hydrogen peroxide and ethyl alcohol may also be used, (135). After this has been done the impression surface is dried with air.

A Copper band impression of an individual tooth is silver plated in the following way:

1. The outer surfaces of the band are covered with a thin
sheet of wax. If a compound or acrylic stop has been used to cover the
the occlusal end of the band, this is also covered with the wax.

2. The copper band is attached to the cathode holder so that
there is intimate contact between the margin of the band and the metal
portion of the cathode holder (138). A silver or copper insulated
wire — approximately 18 gauge — may be used instead of the cathode
holder (134).

3. A small brush is used to deposit dry silver powder to the
surface of the impression. The powder is worked into all areas to be
plated with a stripping action. If spotty areas are observed, the
process is repeated. The excess powder is blown out completely and
should reveal a satiny surface of uniform coverage (135).

4. A sheet of 30 gauge wax is wrapped around the band and
extended just slightly beyond the gingival end of the band.

5. The silver—burnished impression is filled with the silver
cyanide solution from the tank; care being taken not to trap air bubbles.
This is then placed in the tank solution and attached to the cathode
with the open end of the impression facing the silver anode. Myers (150)
suggests the use of a small pipette to fill the impression with cyanide
without trapping air bubbles.

6. The electric current is turned on and the current adjusted
to about 5 ma. After 5 — 10 mins. the impression is examined to see
that all surface has an initial silver deposit. If bare spots have
appeared the impression is removed and dried, the spots are reburnished
with silverpowder, and the impression replaced in the tank.

After 30 mins. the current is raised to 7 ma. where it remains
from 4 to 6 hours. A satisfactory die may be obtained in as little as
four hours, but a slower overnight plating with less amperage is
preferred because it produces a denser, finer grain deposition of silver
than the faster plating (135). If too high a current density is
initially employed, the deposited silver will look gray and will be
accompanied by a bubbling of the solution. This results in the
deposition of a powdery silver surface which usually has bubbles (150)
and is also very brittle (138).
7. When the plating is completed the impression is removed from the solution, rinsed and dried. The anode should also be removed, washed and laid aside at this point. The die may now be poured in stone or low fusing alloy, allowed to set and trimmed in the usual way. 

A tray impression is silverplated as follows:

1. The impression is cleaned as was described for the copper band impression.

2. If a metal tray was used to take the impression, the edge of the tray is brought into contact with the cathode holder or wire and the remainder of the tray is covered with wax. If a plastic tray was used, a hole is drilled through the tray and the impression material in the palatal area. The wire may then be used to conduct the current from the impression surface to the cathode through this hole.

More than one wire may be used, the number being varied to suit the size of the impression e.g. two wires are usually used for impressions involving up to five teeth. Single strand 20 gauge copper wire with plastic insulation is usually used (150). 3 - 4 inch lengths are cut and the insulation stripped about \( \frac{3}{8} \) inch at one end and \( \frac{1}{4} \) inch at the other. The \( \frac{1}{4} \) inch end is cut obliquely with side cutting pliers to make a sharp point which can be inserted readily into the rubber base impression material.

Two wires are placed one on either side of the area containing the tooth preparations and far enough away from them to avoid any possible distortion. The wires are now stabilized by twisting them together close to the impression and the bared ends are twisted together to facilitate their attachment to the plating electrode of the bath (150).

3. All portions of the impression which are not to be plated are now covered with four or five coats of masking solution and allowed to dry (138).

4. The area left exposed is dusted with the silver metallizing powder and burnished in with a sable brush. The silver powdered surface must be extended to make contact with the cathode holder or wire.
5. The impression is filled with some plating solution with a pipette, care being taken not to trap air. It is now attached to the cathode holder and lowered into the plating bath.

6. The current is switched on and the amount of milliamperes to be used is calculated by allowing 10 ma. per tooth to be plated with an additional 10 ma. for each additional area comparable to that of a tooth surface (14) (134) (135) (138) (150). After 5 - 10 min. in the solution, a uniform, clean white layer of silver should be deposited on the metallized portion of the impression. The impression is checked and if satisfactory the normal plating procedure is carried out, overnight plating being recommended (134). If individual dies, are to be cut at a later stage, then the flash plated surface is dried at the examining point and molten wax is flowed on all areas that do not require a build up of plating. This allows the dies to be sectioned more easily, and gingival margins to be trimmed.

7. Stone or low fusing metal may be poured and the dies and cast completed.

COPPER ELECTROPLATING.

The set up and technique for copper electroplating is essentially similar to that used for silver electroplating; only the differences will be discussed. These are as follows: -

A copper anode is used instead of a silver anode and a solution of copper sulphate is employed as the electrolyte. Phillips and Dettman (154) suggest the following as a formula for an electrolyte used for copper plating.

Copper sulphate, anhydrous 225 - 250 Gm.
Sulphuric acid, conc. 75 ml.
Phenol 10 ml.
Ethyl alcohol 25 - 50 ml.
Distilled water 1,000 ml.
A similar solution has been suggested by Peyton (14). The copper sulphate and copper anode are sources of the copper which is deposited, the sulphuric acid increases the conductivity of the solution and the phenol and alcohol serve to assist the penetration of copper ions to the deeper parts of the impression as well as to improve the "throwing power" of the solution. Other additives such as dextrose and molasses may be used. It is better to allow the freshly mixed bath to age for some days before it is used as a better result is usually obtained.

It is necessary to filter the bath occasionally in order to remove "slag" etc. which collects on the bottom. The container is usually of a glass type and should hold one or two quarts of solution. The ammeter should have a range of 0 to 1,000 ma (138). The amount of current applied is either similar to that used in silverplating, or a little greater, being about 15 ma for a single tooth impression (14).

Metallic powder is burnished into the surface of the impression in a similar way to the silver plating technique. Selberg (155) suggests a metalizer composed of Hannau's colloidal graphite, Hannau's silver powder, and a 2% solution of aerosol. About equal quantities of silver powder and colloidal graphite are mixed with the 2% aerosol on a glass slab with a small brush. This is then carried to the impression where the surface is thoroughly saturated by a pumping action in the areas where the copper deposition is required. Excess material is dispersed by a stream of air. Bronzing or copper powder may also be used.

Phillips and Dettman (154) suggest that a superior result may be obtained by depositing a silver film approximately 2 millionths of an inch thick on the surface of the impression before it is copperplated. This can be deposited evenly over the surface of an impression by the chemical reduction of an aqueous solution of silver nitrate. However this suggestion has been made when using a compound impression in a copper band and whether a similar result can be obtained with the elastic impression materials is not clear.

All other materials, plating times, manufacture of casts etc. are completed similarly to methods previously discussed.
The following conclusions, as stated by Phillips and Schnell (147), may be listed with regard to metal electrodeposition onto the surface of Thiocols and silicones.

"(i) Both Thiokol and silicone impressions can be plated, either in a basic silver cyanide or in an acid copper sulphate bath.

(ii) Throwing power and reliability of the basic silver bath was markedly greater than for the acid copper bath used.

(iii) The very finely powdered metals or alloys can produce more accurate surface detail than a brushed on colloidal graphite film.

(iv) Routinely, the most accurate electroformed die, with the best surface detail, was obtained when Thiokol was metallized with silver powder and plated in the basic silver cyanide bath.

(v) The copper electroformed die shows less distortion than the silver die when a silicone impression is plated, but it is doubtful whether electroplating of a silicone, is to be recommended because of distortion of the impression during plating.

(vi) Silver powder is recommended for metallizing prior to silver plating, and bronzing or copper powder metallizing prior to copperplating.

(vii) When a metal die is desired, a silver plated die from a Thiokol impression is recommended."

ADVANTAGES OF ELECTROFORMED DIES (138).

1. They are stronger.
2. They have better marginal definition.
3. Many wax patterns can be waxed up without fear of destroying any detail.
4. Less chance of injuring the margins of the die during the finishing of a casting.
5. The problem of expansion or contraction of the stone material is not present.
6. Undercuts in the preparation are more easily detected on an electroformed die.
7. An electroformed die facilitates the spot grinding of porcelain when a repair of a pontic is being attempted.

8. High spots on the occlusion are easily detected without the use of carbon paper.

There has been some doubt created as to whether the electroformed die technique is worthwhile. This is because the improved stones available at the present time have been specially prepared for the indirect technique; and they possess a minimum amount of setting expansion and a superior surface smoothness and hardness.

A slight amount of extra care associated with the use of these newer stones may thus be quite sufficient to produce equal results to those obtained by the much more involved and lengthy system of metal electrodeposition.
Conclusion

The elastic impression materials used in Crown and Bridgework have different physical properties and each has certain advantages or disadvantages when compared with the others. An understanding of the physical properties and the limitations of each material is necessary for its successful use in Clinical Dentistry.

Impression making is a controversial subject. There is no definite procedure or technique which will fill all requirements. However, the basic principles can be applied generally and the techniques and manipulation of these elastic impression materials can be adapted to comply with the individual requirements of the case in question, within the limits of ability and skill of the Dentist.

The Dentist, unlike the Physicist, has no concept of true accuracy. Anything that "looks" accurate is not sufficient. As impression taking and die making represent about one fifth the total procedure required for a bridge or crown when using the indirect technique, it is extremely necessary that the materials and techniques used are of the highest order in all their properties and phases of procedure.

This review has attempted to survey the elastic impression materials, their composition and properties, as well as their techniques of impression procedure and the various methods of obtaining dies and casts from such impressions in Crown and Bridgework.
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