Dental Technology and Materials for Students

SEVENTH EDITION

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Preface

A considerable proportion of the text of this book has been published previously, through six editions, as "Dental Mechanics for Students". An attempt has now been made to present under one cover the majority of technical procedures with which a dental undergraduate may be expected to make himself familiar; not with the object of becoming personally an expert technician, but so that he will be aware of the inherent problems of dental technology and can advise his technician, and appreciate the technical difficulties that may arise in any particular undertaking.

None of this knowledge can be acquired without an understanding of the composition, properties, and handling characteristics of the materials involved; in particular how they should be manipulated to avoid abuse and to produce the optimum results of which each one is capable. To this end, therefore, chapters have been included which it is hoped will contribute to students being able to get the best possible results from the materials they use in technological courses.

It is hoped also that dental technicians themselves will find the book instructive in helping to bridge some of the gaps between laboratory and clinic.

Some long established prosthetic techniques, now rarely used, or needed, have been eliminated from the text which has been revised completely to bring it up to date. Advanced specialist procedures such as fixed orthodontic appliances and maxillo-facial technology have not been included since they are better described in more specialized publications.

The S.I. system of measurements is used throughout. In this system, the units of length and mass are the metre and kilogramme; the unit of force is the newton. Previously, units of force commonly used were the pound-weight and the kilogramme-weight, which are the forces exerted by a mass of one pound and one kilogramme respectively. These units do not fit into any coherent system and are not true units of force, since the force exerted by a given mass is that mass multiplied by the acceleration due to gravity which is dependent upon geographical position. If the acceleration due to gravity at a place is known, then the force exerted by the mass is known and the result obtained is expressed in true units of force which are universal.

The S.I. unit of force, the newton (N), is defined as that force, which, when applied to a body having a mass of one kilogramme, gives an accelera-

tion of one metre per second per second. Therefore, the force exerted by a mass of 1 kg. is the mass multiplied by the acceleration due to gravity at that place, which is of the order of 9.8 m/s^2.

$$\text{That is 1 kg. wt.} \equiv 1 \times 9.8 \text{ kg. m/s}^2$$
$$\equiv 9.8 \text{ N.}$$

To simplify comparison of force units with previously published results, it can be seen from the above equation that the force of 1 kg. wt. is approximately equal to 10 N.

Many colleagues have made helpful suggestions for the furtherance of this publication and the authors are grateful to them. Their thanks are also due to the publishers for allowing the use of some illustrations from the 4th edition of "Partial Dentures".

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Contents

CHAPTER 1

Impression materials

Before constructing any prosthetic or crown and bridge restoration it is necessary to obtain a *model*, or positive likeness of the patient's mouth, from an *impression* or negative likeness.

The materials used for taking impressions can be divided into two groups:

(1) Rigid

These materials are rigid when set and are generally used for taking impressions of non-undercut areas, such as resorbed edentulous ridges.

This group includes impression plaster, compound, zinc oxide-eugenol paste, and wax.

(2) Elastic

These materials exhibit softness and elastic recovery when set; they are used for taking impressions of undercut areas, for example, when standing teeth are present. In addition, they are widely used for impressions of non-undercut areas in most conservation techniques.

This group consists of alginates and the elastomers (elastic polymers) such as polysulphide, silicone, and polyether materials. Before discussing individual materials, it is necessary to consider, in general, the properties required of any materials used for taking impressions.

In use, the material changes from a fluid to a solid and three stages have to be considered. These are:

1. The fluid material. This is obtained by either mixing components or heating the material until it exhibits plastic flow.
2. The setting material. In this stage the material changes from a fluid to a solid.
3. The set material. This stage must be reached whilst the material is in the mouth.

An impression material must possess certain properties which include suitable values for:

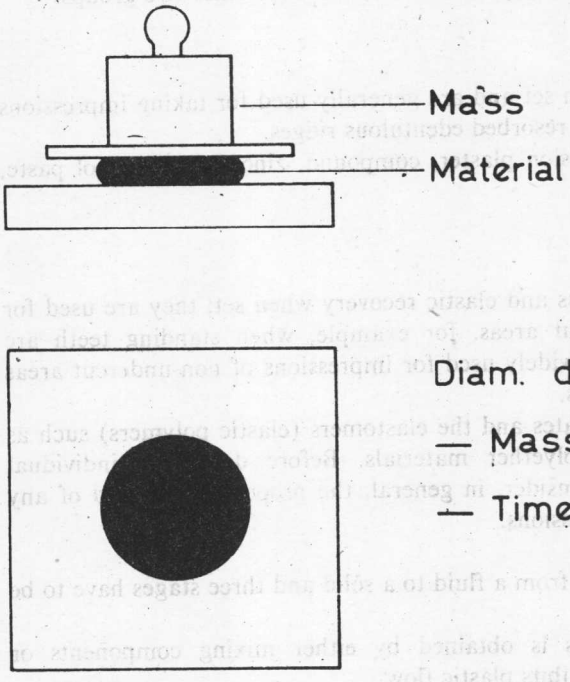
(a) the consistency of the fluid material;
(b) the setting characteristics of the material;
(c) the dimensional stability of the set material;

additionally, for elastic materials, the elastic recovery and sometimes rigidity should be known.

The environmental conditions under which these properties are determined are also important, particularly for impression materials whose setting reaction is markedly dependent upon temperature. The determination of these properties will now be discussed.

CONSISTENCY OF THE FLUID MATERIAL

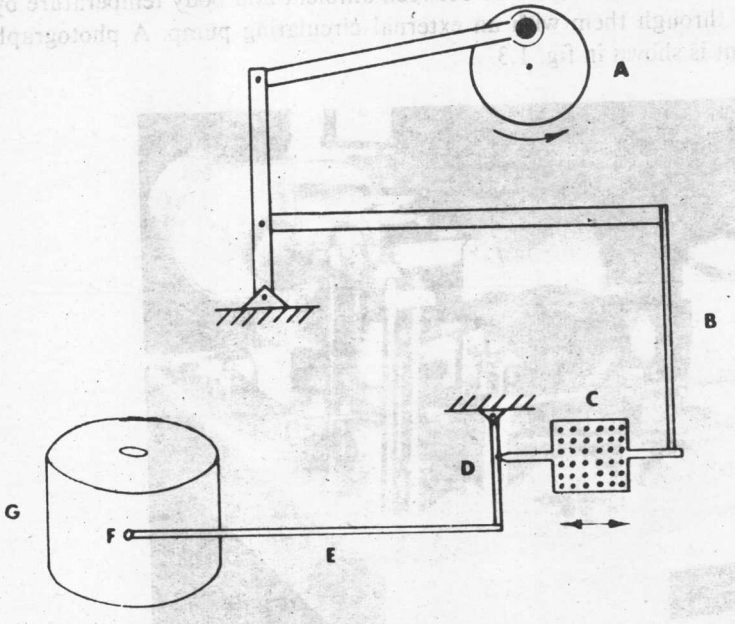
The consistency or fluidity is a matter of personal preference, but its magnitude can be estimated using a simple parallel plate plastimeter shown in fig. 1.1.



1.1 Parallel plate plastimeter.

For a given volume of material (0·5 ml), the two variables which affect the diameter of the disc produced are mass, and the time for which this mass is applied. Some standard tests employ a 500 g mass for 8½ minutes: during this time the material will have changed from a fluid to a solid and the result will depend not only on consistency but also on setting time. It has been shown that in order to exert the same pressures in an impression material as are exerted in the mouth, the mass should be of the order of 1500 g, and the time should be as short as is practically possible, i.e. 5 seconds. The test should be performed under

ambient conditions (20°C and 50 per cent relative humidity) at the time when the impression is inserted into the mouth and this, of course, is dependent upon the type of material used: for silicones, which generally set quickly, a time of $1\frac{3}{4}$ minutes after the start of mix is most appropriate, whilst 2 minutes would be used for alginates and zinc oxide-eugenol pastes, and $2\frac{3}{4}$ minutes for the slow setting polysulphides. When, after applying a mass of 1500 g for 5 seconds, the diameter of the resultant disc is less than 20 mm the material is extremely viscous and quite often partially set. When the diameter of the disc is of the order of 30–32 mm the material is very fluid; an indication of consistency can therefore be obtained from the diameter of the discs produced.

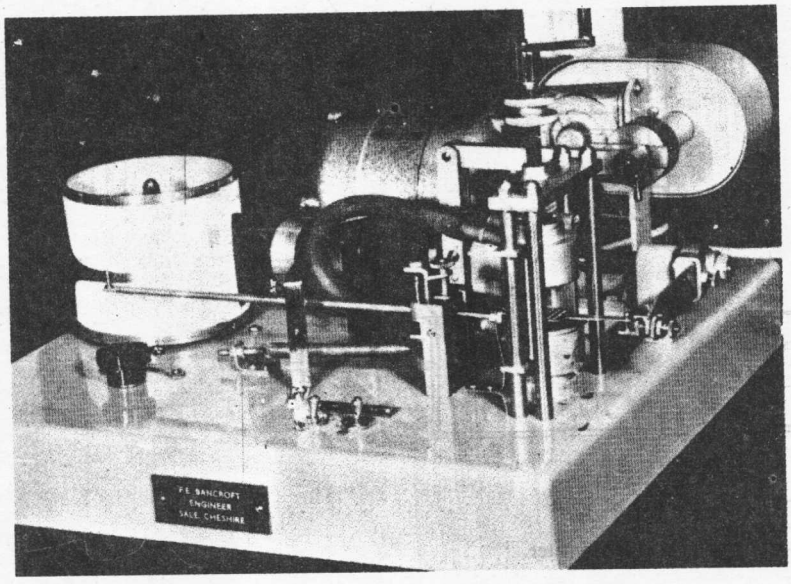


1.2 Line diagram of reciprocating rheometer.

SETTING CHARACTERISTICS OF THE MATERIAL

The setting characteristics of impression materials can be assessed by the use of an instrument developed for this purpose, a reciprocating rheometer. This instrument, a line diagram of which is shown in fig. 1.2 is particularly suitable for materials whose viscosity changes are large. It consists of an electric motor connected to a gear box which drives an eccentric wheel (A) connected to a series of levers. The rotary motion is changed to reciprocating and the spring beam (B) moves back and forth at a speed which can be selected by the gear box and at a distance selected by the eccentric. For standard tests the spring beam produces a

force of 1·8 N when deflected 0·1 mm. The beam movement is set at 1.0 mm and the speed at 10 cycles per minute. The end of the spring beam is connected to a removable horizontal central plate (C) (24 mm square × 1 mm thick and containing 36 perforations of 1·5 mm diameter); this in turn is connected through a lever (D) to a pen arm (E) which produces a maximum deflection of the pen (F) of approximately 60 mm, which can be adjusted by a pen sensitivity screw. The pen writes on a recording drum (G) which has a circumferential speed of 5 mm per minute. In addition, two water-jacketed horizontal plates can be positioned above and below the central plate (C) and parallel to each other; the distance between these plates is 3 mm for all tests. The temperature of these plates can be maintained at any value between ambient and body temperature by pumping water through them with an external circulating pump. A photograph of the instrument is shown in fig. 1.3.



1.3 Reciprocating rheometer.

When carrying out a test the mixed material is placed on both sides of plate C, which is then positioned between the horizontal plates which in turn are adjusted to be 3 mm apart. The motor is then started and plate C moves to and fro within the material, the degree of movement decreasing as the material becomes more completely set.

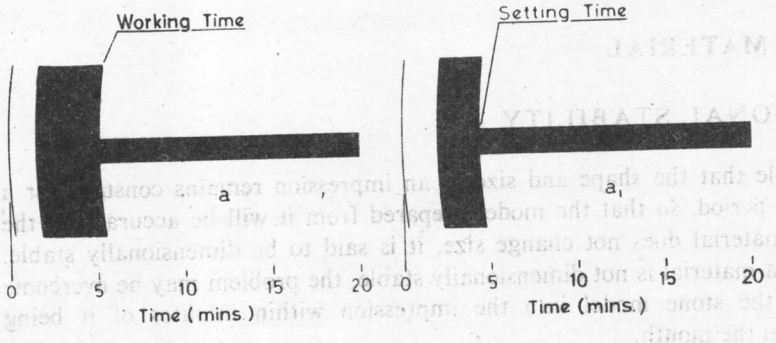
Tests are performed at two temperatures (a) at room temperature standardized at 21 °C, and (a_1) at temperatures which the material would attain in the open mouth, which is 30 °C for alginate and 32 °C for other impression materials.

For room temperature tests the material is inserted into the instrument 1¼

minutes after mixing has commenced, whilst for mouth temperature tests the material is inserted at the same time as the material would be inserted into the mouth; that is, 2 minutes for quick set materials and 3 minutes for slow set materials.

The logical terms which should be used in discussing the setting characteristics of any impression material are initial and final setting times, which indicate the beginning and ending of the setting process at a particular temperature: the time interval between the initial and final set is the setting range. Under ambient conditions, the initial setting time becomes the time available for manipulating the material, or the *working time*. Under oral conditions, the final setting time indicates the time when the material is completely set and can be removed from the mouth and should simply be called the *setting time*.

Consider an ideal material, whose viscosity remains constant for a reasonable length of time, say 5 minutes at room temperature, then suddenly increases so that a solid is formed immediately: in this case, the setting range is zero. A trace of such a material obtained on the reciprocating rheometer would be as shown in fig. 1.4a, and the time available for mixing and manipulating this material, that is, the working time, will be 5 minutes. Assume that another mix of this same material is inserted into the mouth 2 minutes after mixing. The rate of setting will be increased by the increase in temperature and therefore the change from fluid to solid will occur earlier, say, 4 minutes (fig. 1.4a_1): this is the time when the material is set and has attained its optimum properties, that is the setting time. This ideal material displays a property never found in real materials; that is, the sudden change from fluid to solid or zero setting range, which would be desirable so that the working and setting times would be demarcated sharply. As a result of this sudden set of the ideal material it would always have a setting time under oral conditions shorter than the working time under ambient conditions. The reverse is generally true for real materials. If a real material is deformed after it has started to set it is probable that residual stresses will be present in the set material which will reduce its dimensional stability. Also, if the absolute setting time is long, and an impression is removed before it is completely set, permanent deformation of the material will probably occur.



1.4 Traces for ideal impression materials.

Typical traces for impression plasters, zinc oxide-eugenol pastes, alginates, silicones, polysulphides, and a polyether are shown in fig. 1.5. The left hand column relates to setting at room temperature whilst the right hand column is for materials setting at mouth temperature.

The working and setting times are indicated on the traces.

It can be seen from fig. 1.5 that real materials set gradually, some more gradually than others, and that the polysulphides are affected more by changes in temperature than are the silicones. It is not possible to define working and setting times absolutely since the material starts to set and its fluidity decreases immediately after mixing. A compromise must be made and, in fact, a material is still usable some time after the onset of polymerization. Similarly, a material is not truly set until it has attained optimum properties, which may take a considerable time.

Since there is no method of defining absolute working time from the traces, or for that matter, from any viscosity measurements, the best that could be done was to obtain empirically assessed working times from clinicians on the same mixes as those used to obtain the traces. This indicated that the working time was the time when the width of the trace was nearly 95 per cent of the width of the trace when the material was first inserted into the instrument.

The working time can therefore be defined as the time when the width of the trace, obtained at room temperature, is 95 per cent of the width of the initial trace. The setting time is similarly defined as the time when the trace, obtained under oral conditions, becomes parallel. The justification for this definition is that the results so obtained are realistic and the material at this stage has attained almost the same degree of set as at 20 minutes.

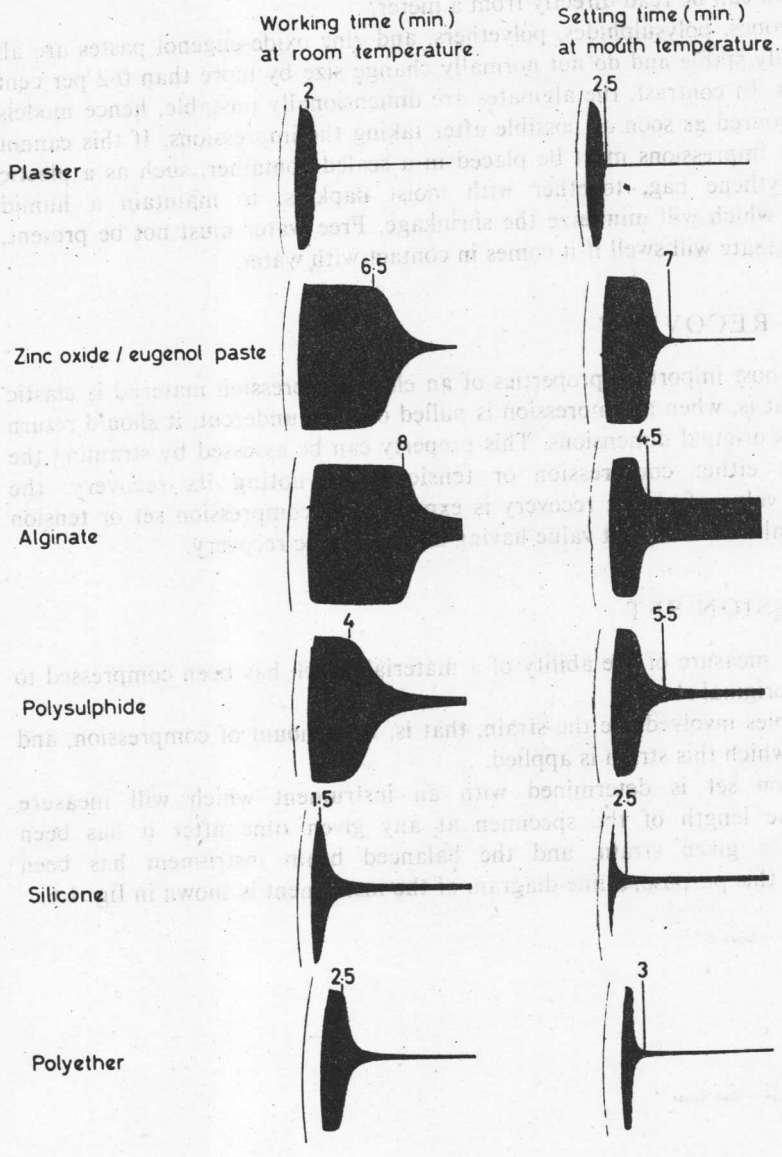
The traces can provide other information in addition to the working and setting times; the setting characteristics of the materials, that is the rate of increase of viscosity and the development of optimum properties, can readily be assessed graphically, whilst the width of the trace after completion of set is an indication of the flexibility of the set material. Further, traces can be compared directly with the trace which would be obtained for an ideal material (fig. 1.4).

THE SET MATERIAL

DIMENSIONAL STABILITY

It is desirable that the shape and size of an impression remains constant for a considerable period, so that the model prepared from it will be accurate. If the impression material does not change size, it is said to be dimensionally stable. However, if a material is not dimensionally stable, the problem may be overcome by pouring the stone model into the impression within minutes of it being removed from the mouth.

Dimensional stability is most conveniently measured by means of a dis-



1.5 Typical traces for different impression materials.

placement transducer which converts the change in dimension into an electrical output which can be read directly from a meter.

The silicones, polysulphides, polyethers, and zinc oxide-eugenol pastes are all dimensionally stable and do not normally change size by more than 0·2 per cent in six hours. In contrast, the alginates are dimensionally unstable, hence models should be poured as soon as possible after taking the impressions. If this cannot be done the impressions must be placed in a sealed container, such as a plastic box or polythene bag, together with moist napkins, to maintain a humid atmosphere which will minimize the shrinkage. Free water must not be present, since the alginate will swell if it comes in contact with water.

ELASTIC RECOVERY

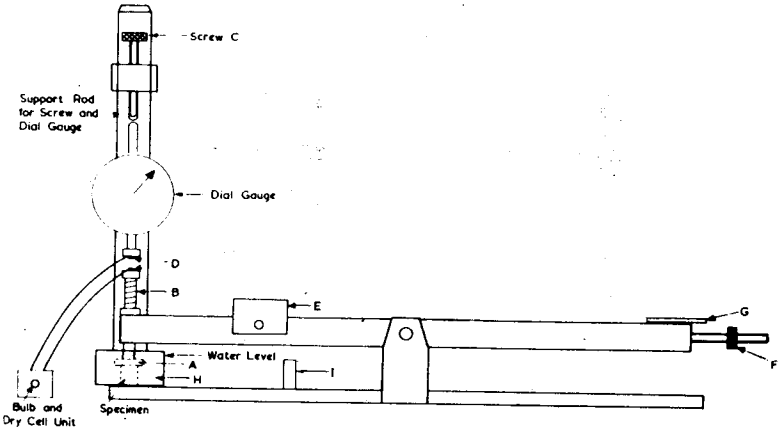
One of the most important properties of an elastic impression material is elastic recovery, that is, when an impression is pulled over an undercut, it should return rapidly to its original dimensions. This property can be assessed by straining the material, in either compression or tension, and noting its recovery: the quantitative value of elastic recovery is expressed as compression set or tension set, a material with a low set value having a good elastic recovery.

COMPRESSION SET

This test is a measure of the ability of a material which has been compressed to return to its original shape.

The variables involved are the strain, that is, the amount of compression, and the time for which this strain is applied.

Compression set is determined with an instrument which will measure accurately the length of the specimen at any given time after it has been subjected to a given strain, and the balanced beam instrument has been developed for this purpose; a line diagram of the instrument is shown in fig. 1.6.



1.6 Line diagram of balanced beam instrument.

The horizontal platten (A) has a larger diameter than that of the specimen and the platten is connected to the beam by means of a screwed rod (B) so that the horizontal position of the platten relative to the beam can be adjusted accurately. Above the rod (B) is mounted the dial gauge which is used to ascertain the position of the beam at any time; this positioning is made more precise with the screw (C) and electrical contacts (D) and associated circuit. The beam can be balanced by means of the mass (E) and adjustable screw (F).

Any desired minor load can be applied to the specimen, in order to obtain an initial reading, simply by placing a mass, usually 5 g on the scalepan (G) before the beam is balanced. When the 5 g mass is removed from the scalepan the minor load is immediately transferred to the specimen.

The 20 mm high mould which is used to prepare the specimens is placed in the container (H) under the platten (A) and the contacts (D) are made to touch each other by means of the screw (C) acting through the dial gauge, and thus the original length of specimen is established. If a 20 per cent strain is to be applied, then the 20 mm long specimen must be compressed by 4 mm. In order to do this, the mould is removed and the platten lowered 4 mm with the screw (C) acting through the dial gauge: the platten is now in the position it must occupy when the specimen is under compression. In order to prevent the platten being lowered beyond this position the stop (I) is adjusted so that it contacts the lower surface of the beam. Screw (C) is released so that the beam is free to pivot, and the instrument is now set to produce a 20 per cent strain quickly and accurately.

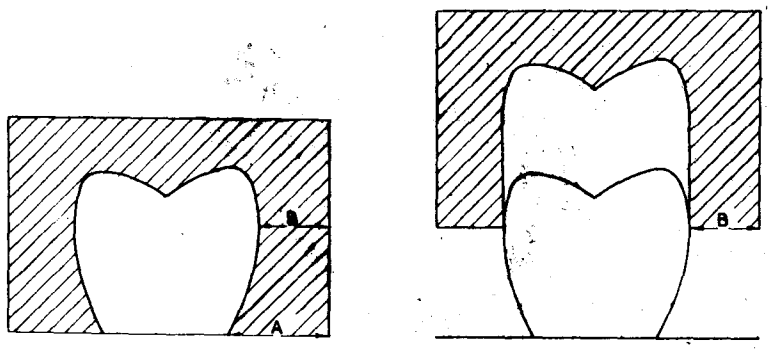
In the case of alginates, the prepared specimen is covered with a moist napkin and trasferred to the instrument. It is aligned under the platten 4½ minutes after the start of the mix; half a minute later the dial gauge reading is recorded (x). The specimen is immediately strained by 20 per cent by hand pressure on the beam and this strain is maintained for 5 seconds. The strain is then released and the change in length of the specimen is obtained by reading the dial gauge (y) 3 minutes later.

The compression set is calculated using the following equation:

$$\text{Compression set} = \frac{x - y}{20} \times 100 \text{ per cent}$$

In clinical practice, the material is compressed against the side of the tray when the impression is removed. The strain induced is dependent upon the shape and tilt of the tooth, and upon the thickness of material between the tooth and the tray, as shown in fig. 1.7 where it can be seen that the amount of strain induced can be reduced by using a thicker section (A) of impression material. It is estimated that this strain is often of the order of 20 to 30 per cent, but of short duration, say 5 seconds.

Another factor which influences the results obtained is the environment under which the test is performed. Ideally the open mouth environment should be used, but since this is difficult to achieve, the alginate specimen is covered with a moist napkin. Since the elastomers possess superior elastic properties, they can be used in more demanding situations, and the compression set test is therefore more



$$\text{Compressive strain} = \frac{A-B}{A} \times 100\ \%$$

1.7 Diagram to illustrate that the compressive strain induced in an impression material is dependent upon its thickness.

severe than for the alginates; a 30 per cent compression is used instead of 20 per cent. Under these conditions, compression set values for silicones should be less than 1·5 per cent, for polysulphides and polyethers less than 3·5 per cent, and for the alginates less than 4 per cent. These values indicate the actual deformation of the material which might occur in practice.

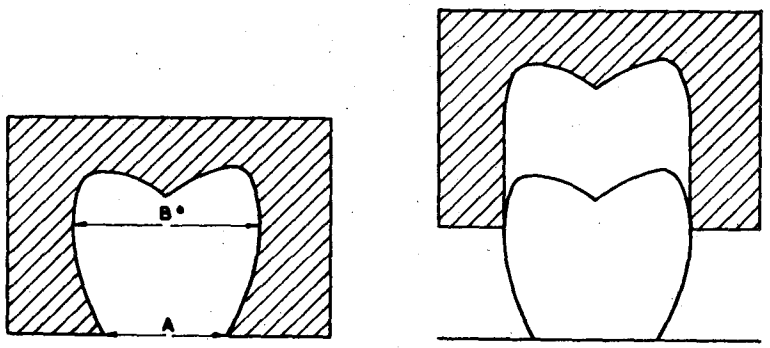
TENSION SET

The elastic properties of impression materials in compression are useful for assessing their suitability, but, in practice, the compressive strain applied depends, amongst other things, upon the thickness of material, which varies tremendously particularly when stock trays are used.

However, the tensile strain induced for a particular tooth is independent of material thickness, in fact, it is dependent upon tooth dimensions, as illustrated in fig. 1.8: tension set is therefore a more fundamental property than compression set, which, as previously stated, is also dependent upon the thickness of the material used.

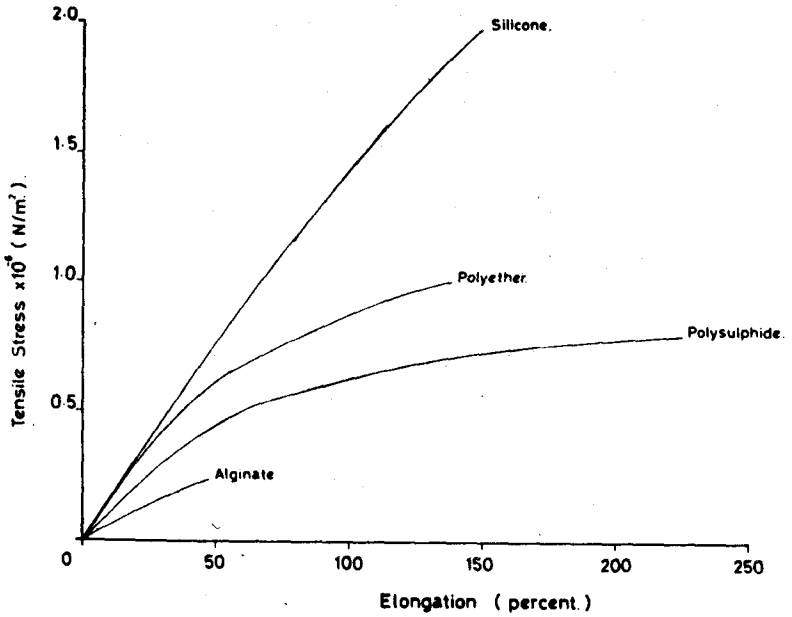
Tensile tests are performed on dumb-bell specimens which are pulled at a high strain rate of 50 cm/min. The first tests that are usually performed are those in which the specimens are taken to breaking point and the relationship between tensile stress and elongation for different types of materials is shown in fig. 1.9. The first conclusion to be drawn from these curves relates to the strengths of the various materials, but the most important observation concerns the percentage elongation at break, which is an indication of the extent to which the material can be 'stretched' before it tears. The elastomers generally have high values for elongation, but the alginates rarely attain 50 per cent.

Tension set values are best determined using a jig which is capable of



$$\text{Tensile strain} = \frac{B-A}{A} \times 100\ \%$$

1.8 Diagram to illustrate that the tensile strain induced in an impression material is dependent upon tooth dimensions and not thickness of material.



1.9 Variation of tensile stress with elongation for elastic impression materials.

extending the specimen rapidly and which incorporates a vernier gauge to measure the specimen length at any time. By this means, a tensile strain of 50 per cent can be applied in 1 second, maintained for a further 1 second and immediately released. The recovery and hence the tension set can be determined