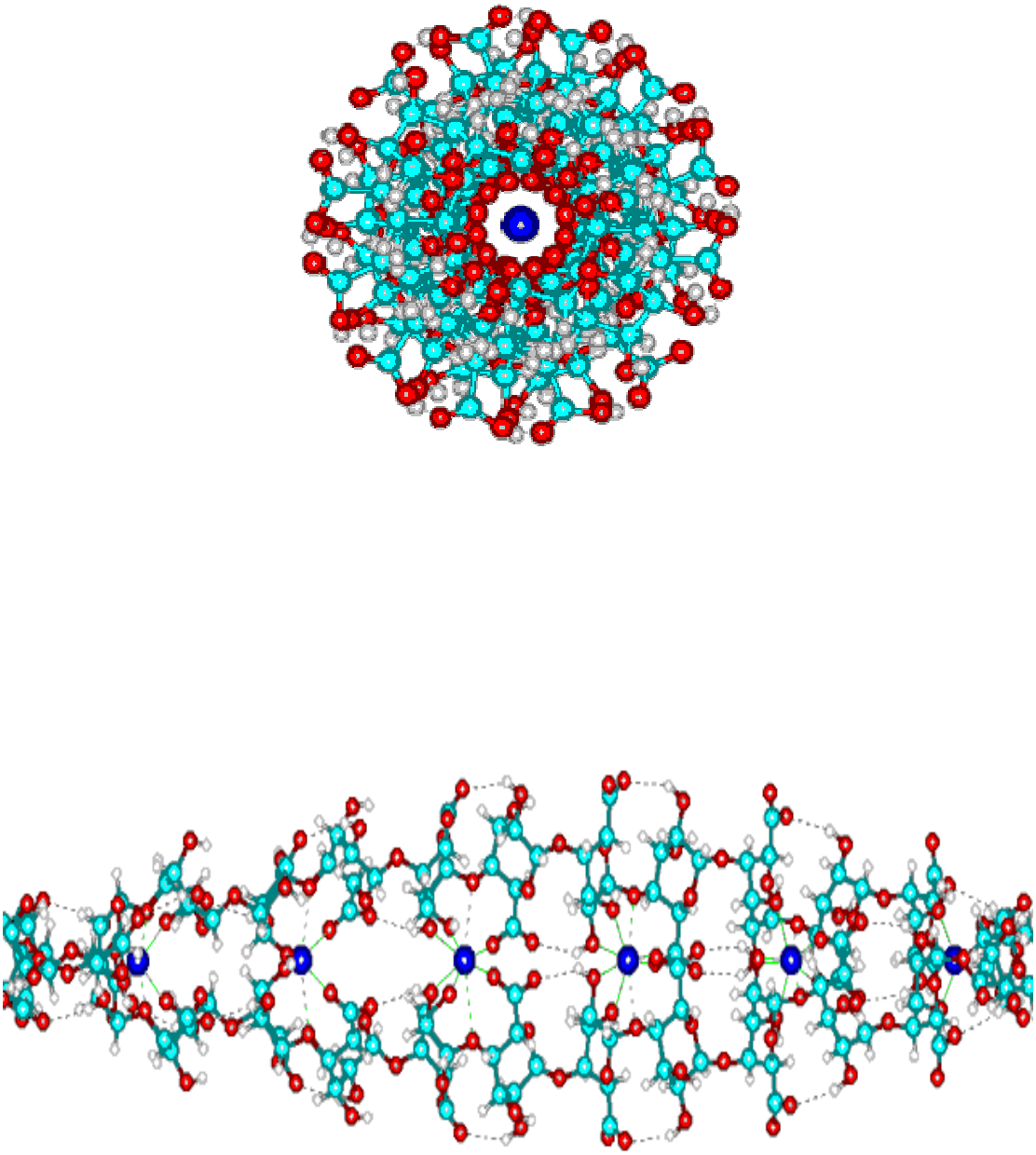
FRONTISPIECE Diagram of the alginate molecule



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An Investigation of the Dimensional Stability of Dental Alginates

A dissertation submitted for the degree

Master of Science (Dentistry)

to The University of Sydney

By

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Abstract

Dimensional stability was defined by Nicholls (1977) as “the ability (of a material) to maintain accuracy over time”, and the result of loss of accuracy, “distortion”, as “the relative movement of a single point, or group of points, away from some originally specified reference position such that permanent deformation is apparent”. Maintaining dimensional stability of dental impression materials is vital if the impression cannot be cast (in stone) soon after removal from the mouth.

Dental irreversible hydrocolloid (alginate) is a major dental impression material used worldwide in many clinical procedures. However, alginate is dimensionally unstable and changes its dimensions (suffers “distortion”) after removal from the mouth. With storage times of more than ten minutes, alginate begins to distort, and after one to three hours (depending on the product and storage conditions) cannot be used for many clinical purposes, especially fixed prosthodontics such as crowns and bridges (Hampson 1955, Skinner & Hoblit 1956, Wilson & Smith 1963, Rudd et al. 1969, Miller 1975, Inohara 1977, Schoen et al. 1978, Coleman et al. 1979, Linke et al. 1985, Habu et al. 1986, Peutfeldt & Asmussen 1989, Mathilde & Peters 1992, Khan & Aziz Sahu 1995, Eriksson et al. 1998, Schleier et al. 2001, and Donovan & Chee 2004). This loss of accuracy, due to dimensional instability, manifests as a time-dependent distortion of the poured stone cast, and thus any prosthesis fabricated will not fit in the mouth.

With the introduction of the more stable elastomers in the 1950s (Stackhouse 1970, Glenner 1997, Brown 2003) that could be stored for days if necessary, without loss of accuracy, the alginates fell out of favour for fixed prosthodontics. Recently, there has been a resurgence of interest in alginate for use in dental procedures where dimensional stability is critical (Peutzfeldt and Asmussen 1989, Eriksson et al. 1998). This in part is due to the favourable properties of alginate not found in the elastomers. Of greatest significance is that alginate hydrocolloid is hydrophilic, whereas elastomers are hydrophobic (Phillips & Ito 1958, Glenner 2004). Thus, alginate materials are able to reproduce wet oral areas with greater precision and to produce a superior "fit" of, say, a gold casting produced by the Lost Wax technique (Skinner and Phillips 1982).

A number of reports have been published which investigate newer alginate materials that are claimed to be more dimensionally stable than older formulations. Puetzfeldt and Asmussen (1989) found that a newer alginate[1], if stored at 100% relative humidity, retained accuracy over 24 hours that was equivalent to that of the elastomers. More recently, the manufacturer of another alginate[2] has claimed equivalent dimensional stability to the elastomers for up to 100 hours, and, whilst this claim has not been reported on in the literature, the present thesis will show that, under favourable conditions of storage, the material maintained clinically useful accuracy for up to 100 hours.

Another approach to improving the accuracy of alginate impressions has been to combine reversible hydrocolloid with alginate (the “Bilaminar” technique). Frederick and Caputo (1997) confirmed that the new agar reversible hydrocolloids are just as accurate (at the time of removal from the mouth) as the new elastomers. Mathilde et al. (1992) and Eriksson et al. (1998) have shown that several of the “bilaminar” impression techniques for fixed prosthodontics, where alginate is used as a tray material supporting a reversible hydrocolloid (agar) wash, are as accurate and dimensionally stable as elastomers for up to three hours.

However, these studies are difficult to interpret due to lack of uniformity in the testing methods, and the fact that there is no regulatory standard available to measure dimensional stability for dental alginates.

The International Standard (IS) for alginate impression materials (ISO 1563:1990E) contains no specification for dimensional stability, and thus places no requirement for manufacturers to state dimensional stability properties on their labels. In contrast, ISO 4823:1992(E) specifies the IS for elastomeric dental impression materials, and it does specify a requirement for dimensional stability (less than 1.5% distortion after 24 hours). Further, the IS sets a method for determination of dimensional stability. Briefly, this method (the Optical Method) uses a travelling optical microscope to measure the accuracy of the distance between score lines on an impression of a test grid, at various time periods. The American Dental Association Specification No. 19 for

[1] *Blueprint*, by de Tray, Germany, Halas, Australia.
[2] *Kromopan 100*, by Kromopan Inc. 1265 Rand Road, Des Plaines, Illinois,USA 60016, Dentsply, Australia.

dental elastomeric impression materials is identical to the IS. There is currently no specific Australian Standard (AS) for the dimensional stability of any dental impression material.

Overview of Experimental Methods

A. The Optical Method

The aim of Part A of this investigation was to:

1. Adapt the Optical Method of the IS for elastomers to be reproducible for dental alginates. This was achieved by using a perforated test tray (to simulate clinical conditions), and measuring the grid pattern on a dental stone button after casting the test impression, rather than direct measurement of the impression, as for the IS.

2. To measure and rank the dimensional stability of a number of locally available dental alginates. Measurements of the test stone buttons proved reproducible, and the results were different for each sample, allowing them to be ranked according to dimensional stability after 50 and 100 hours of storage. The results show that the traditional optical method for measuring dimensional stability, as specified in the IS for dental elastomers, can be adapted to measure the dimensional stability of dental alginates

However, the Optical Method of measuring dimensional stability of dental alginates is cumbersome and time-consuming. It was hypothesised that dimensional stability of dental alginates could be measured more conveniently by finding a thermal property that is directly proportional to dimensional stability. This method could be useful for the rapid determination of relative performance, and allow comparison with a determined benchmark.

B. The Thermal Method

Recently, modern methods of Thermal Analysis, Thermal Gravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC) have been used to rapidly age various polymers, including food alginates (Chinachoti 1996), in order to measure thermal stability. This thesis shows that thermal stability is an indicator of dimensional stability.

The aim of Part B of this investigation was therefore to adapt thermal analysis techniques to dental alginates, and develop a method to measure their thermal stability. These results were then compared with those for dimensional stability measured by the Optical Method to determine the relationship between thermal and dimensional stability for dental alginates. The results show that current thermal analysis methods of TGA and DSC can be adapted to measure relative dental alginate dimensional stability, and are both rapid and convenient. This study also provides evidence that commercial products differ as regards the property of dimensional stability, and can be ranked accordingly.

C. Practical Application of the Methods

The aim of part C of this thesis was to validate the methods (both optical and thermal) developed in this study by using them to investigate the effect of varying the water/powder ratio on the dimensional stability of dental alginates.

It was shown that dimensional stability is affected by changes to the recommended water/powder ratio, that both the methods detected and measured the changes, and that the results were proportional, in that any percentage change detected by the optical method, was mirrored by the thermal method, confirming that the more convenient thermal methods can be used to measure dimensional stability.

Declaration

This thesis was composed entirely by myself whilst visiting the Department of Chemistry, Faculty of Science, and Department of Dental Materials Science, Faculty of Dentistry, University of Sydney, Australia.

The travelling optical microscope studies were carried out in association with Mr Ken Tyler, Senior Technical Officer, Biomaterials Unit, Department of Dental Materials Science, Faculty of Dentistry, University of Sydney, Australia.

The Thermal Analysis studies were carried out under the supervision of Dr Herbert Chiou within the Key Centre for Polymer Colloids, Department of Chemistry, Faculty of Science, University of Sydney, Australia.

All statistical analysis was carried out by myself with advice from Dr Georgina Luscombe, Queen Elizabeth II Research Institute, University of Sydney, Australia.

I declare that none of the work embodied in this thesis has been submitted towards a higher degree at another University or Institution.

Acknowledgements

I am grateful to my Supervisors, Dr Graham Thomas, Senior Lecturer in Prosthetics, and Professor Mike Swain, Professor of Dental Materials Science, Faculty of Dentistry, University of Sydney, Australia, for their support, guidance, and good counsel during the planning and execution of this research work throughout all of my (part time) candidature.

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Especial thanks to Mr Ken Tyler, Senior Technical Officer, Biomaterials Unit, Faculty of Dentistry, University of Sydney, for his fabrication of the dental alginate impression taking apparatus (“jig”), and Ms Georgina Luscombe, Statistician, Department of Obstetrics and Gynaecology, Faculty of Medicine, University of Sydney, for her help with statistical analysis of the results.

Publications Arising

Publications Arising From This Thesis

Papers in Preparation

Nichols P, Thomas G. *Thermal Analysis: A better way to measure the dimensional stability of dental alginates*. Paper in preparation for submission to the Australian Dental Journal.

Nichols P, Thomas G. *The effect of changes to water / powder ratio on the dimensional stability of dental alginates*. Paper in preparation for submission to the Australian Dental Journal.

Preface

Reliability and Validity of Dental Materials Testing

(From a letter by M.J.Tyas , ADJ, 1990)

"It is axiomatic that a laboratory test should exhibit both reliability (the extent to which the same measure gives the same result on repeated applications) and validity (the extent to which a measure really measures what it purports to measure).

- in the laboratory, validity can be taken as to the extent to which the results predict clinical performance.

- it is well known that results obtained from test of materials on enamel in the laboratory may be unreliable due to the many uncontrolled variables in oral cavity simulation. Coefficients of variation exceeding 20% are common."

The experiments in this thesis were designed to simulate the environment in the dental office and oral cavity, as near as possible.

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