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The interaction of various liquids with long-term denture soft lining materials

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ABSTRACT

Objectives. To study the uptake of liquids, representative of those encountered orally, by long-term denture soft lining materials, and analyze the data in terms of appropriate theories.
Methods. Four proprietary and one experimental soft lining material were investigated, and the weight change presented as a function of time in both aqueous and organic fluids over the course of a year. A separate experiment determined the equilibrium swelling in ethanol of poly(ethyl methacrylate) and poly(methyl methacrylate).
Results. Uptake date for the five soft lining materials in various aqueous solution, coconut oil and HB307 are reported. The experimental value for the equilibrium swelling of poly(ethyl methacrylate) and poly(methyl methacrylate) in ethanol was reported to indicate the solubility parameter of the system.
Significance. The results have been analyzed by relevant theoretical models, which have been shown to explain the experimental data.

1. Introduction

The term soft lining refers to the lining of a denture with an elastomeric type material. Such materials, being easily deformable, will absorb energy during biting [1], and distribute the loads evenly over the whole denture bearing area, thus lessening the deformation of the oral mucosa. This reduces the discomfort when such loads exceed the ability of the tissues to support them and potentially reduces resorption of the residual bone [2]. Clearly, it is highly desirable that such materials do not degrade in the mouth, i.e. do not lose strength or compliance, nor become detached from the denture. The most obvious mechanism of compliance loss is with the so-called soft acrylics, where compliance is achieved by incorporation of a plasticizer, and subsequently lost when the plasticizer leaches out [3]. Some experimental materials have been described which use a polymerisable plasticizer [4,5].

Another approach has been to make a preformed, heat curing dough, comprising a main elastomer from the rubber industry, e.g. polyisoprene, butadiene, styrene copolymers, doughed with a higher methacrylate monomer (n-butyl and above). In this way, it was hoped that the high strength of such elastomers would be of benefit. A number of studies have been made of these systems [6–15]. One disadvantage was that prolonged immersion in water at 37 °C produced a marked deterioration in mechanical properties. This was attributed to peroxide catalyzed scission of the double-bonds

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in diene copolymers, the residual peroxide polymerization catalyst being the source. Hence brominated butyl rubber was investigated; butyl rubber is a copolymer of ~98% isobutyl methacrylate and 2% isoprene [16]. The brominated version was used because it is easier to peroxide cross-link [15].

The loss of strength in water can also, a priori, be due either to certain aspects of water uptake, or the interaction of organic liquids in the diet such as products containing vegetable oils or ethanol. High water uptake can be experienced in otherwise hydrophobic elastomers, with consequent loss of strength, by the presence of water soluble components. Thus Braden and Wright observed water uptake values in a silicone rubber soft liner of >60% [17]. More recent studies are those of Mante et al. on the effect of aqueous solutions on hardness, and Leite et al. on the effect of various beverages on hardness [18,19].

The current study has involved representative proprietary materials from the soft acrylic and silicone types, and an experimental material based on brominated butyl rubber. The test liquids included aqueous, ethanol containing, and paraffinic liquids. However a major objective of this paper was the application of relevant theories to the results obtained.

2. Materials and methods

2.1. Materials

The materials used are listed in Table 1 and further details are listed in Table 2. Eversoft and Vertex are examples of the so-called soft acrylics. Ufi-gel and Molloplast b are silicone rubbers, the latter having dispersed polymethyl methacrylate (PMMA) domains, as indicated by infra-red spectroscopy. Various suggestions have been made as to its exact composition [20,21].

The brominated butyl rubber (BBR), doughed with n-butyl methacrylate and heat cured was an experimental material [15].

2.2. Methods

2.2.1. Sample preparation

A polyether impression material was used to make sheets nominally 1 mm thick, from which 20 mm diameter discs were cut using a cork borer. These discs were invested in dental stone using conventional dental techniques. On setting, the flask was separated and the discs removed to leave a mold ready for the preparation of specimens. Discs were prepared for each of the materials using the manufacturer's instructions.

In the case of the brominated butyl rubber, the monomer liquid was made up with 1% lauryl peroxide (w/w) as initiator and n-butyl methacrylate monomer containing 1% ethylene glycol dimethacrylate (wt/vol) as a cross linking agent. Lauryl peroxide was used instead of benzoyl peroxide, because the decomposition in the former case is lauric acid, and benzoic acid in the latter. Lauryl peroxide has a much lower solubility in water, and consequently will have much less influence on water uptake [20]. 100 g brominated butyl elastomer was doughed with 100 ml of the monomer liquid described above. The curing cycle comprised 2 h at 74 °C, followed by 30 min at 100 °C.

2.2.2. Water and fluid absorption characterization

All specimens were processed according to the manufacturers' directions. A total of 42 specimens were constructed for each denture soft lining material. The specimens were then randomly divided into seven groups of six specimens. Specimens were preconditioned after manufacture by storing in a desiccator at 37 ± 1 °C. The specimens were removed from the desiccator and then after immediately weighing, were weighed at regular intervals until a constant weight was achieved. All readings were taken to an accuracy of ±0.0002 g on an AE Mettler electronic balance (Metler-Toledo Ltd, Leicester, UK). This initial weight (W_0) was noted. After weighing, each specimen was immediately transferred to a wide mouth, amber, screw topped glass jar containing 50 ml of a food simulating liquid conditioned to 37 °C. The immersing liquids selected were distilled water (DW), artificial saliva (AS) (composition shown in Table 3) [22], 3% aqueous acetic acid (3AA) (EC Food Contact Legislation, 2000), 10% ethanol (10E), 50% ethanol (50E), coconut oil (CO) and HB307 (HB) (FDA, 2002). Each glass jar was then stored in an incubator (LABHEAT Model RLCH0400, Boro Labs Ltd, Berkshire, UK) at 37 ± 1 °C. Each specimen was removed at predetermined time intervals using tweezers and carefully blotted to remove excess surface liquid using filter paper prior to weighing. The weights were then recorded. Initial intervals between weighing were short but subsequently were increased. The fluid was unchanged for the duration of the experiment but was topped up after each measurement to maintain a fixed volume.

After a period of 52 weeks, specimens were removed from solution, weighed and then desorbed in an incubator (Gallenkamp Durastat Type 3, LTE Scientific Ltd, Oldham, UK) at 37 ± 1 °C. Specimens were weighed at regular intervals until a minimum weight was reached (W_d). Percentage weight change and percentage solubility were calculated as a percentage of the initial weight. Real percentage uptake was calculated as the sum of percentage weight change and percentage solubility, and desorption diffusion coefficients by the application of solutions of Fick's equations [23]:

$$\%\,\text{Uptake} = \left(\frac{W_t - W_0}{W_0}\right) \times 100 \qquad (1)$$

$$\%\,\text{Solubility} = \left(\frac{W_0 - W_d}{W_0}\right) \times 100 \qquad (2)$$

$$\text{Real}\,\%\,\text{Uptake} = \%\,\text{Uptake} + \%\,\text{Solubility} \qquad (3)$$

where W_0 = initial weight, W_t = weight at time t and W_d = final minimum desorbed weight. The diffusion coefficient was calculated from the slope of the linear parts of the plot [24]:

$$\frac{M_t}{M_\infty} = 2\left(\frac{Dt}{\pi l^2}\right)^{1/2} \qquad (4)$$