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Research Paper

Effect of solvent/disinfectant ethanol on the micro-surface structure and properties of multiphase denture base polymers ☆

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ABSTRACT

Aim of the study: The aim of this study was to evaluate the effect of solvent/disinfectant ethanol on the surface of denture base polymers. Changes in surface roughness, topography and some nanomechanical properties were assessed by SEM and nanoindentation plotted against different concentrations of ethanol on heat cured and autopolymerized polymetyl methacrylate based acrylic denture base polymers.
Materials and methods: Test specimens ($10 \times 10 \times 3\ mm^3$) of heat-curing (HC) and autopolymerizing (AP) acrylic resin were prepared and polished to obtain uniform smoothness which were further grouped into 3 sub-groups HC1, HC2, HC3 and AP1, AP2, AP3 respectively 10 specimens (*n*) in each group. HC1 and AP1, HC2 and AP2, HC3 and AP3 were treated with 99.9%, 70% and 40% respectively for 30, 60 and 120 s followed by analysis of surface roughness (S_a), topographical changes and some nanomechanical properties.
Results: Both HC and AP resins showed changes in their S_a and nanomechanically measured modulus of elasticity and surface hardness after being treated at different concentrations of ethanol and at different lengths of time. Surface changes were most clearly seen in autopolymerizing denture base polymer, especially at the interface region between the PMMA polymer bead and polymer matrix. There was a correlation ($R2=0.83$, $r=0.91$, $P<0.001$) between the time of treatment by ethanol and thickness of the affected area of denture base polymer.
Conclusion: The present study demonstrated that denture base polymers, especially

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autopolymerized denture base polymer is prone for surface crazing and dissolving by solvent/disinfectant ethanol. The interphase region between the PMMA polymer bead and the polymer matrix was most affected by the ethanol.

1. Introduction

Acrylic resins were introduced as denture base materials since 1937 and polymethyl methacrylate (PMMA) is still the most commonly used material in dental prosthesis, denture liners, various orthodontic appliances, temporary crowns (Craig, 1993). PMMA is used in the form of powder–liquid system, mixed at different ratios for controlling the polymerization shrinkage and obtaining resin mixture or dough which is easy to handle (Vallittu, 1994). Monomer liquid system is predominantly methyl methacrylate but there are typically minor quantities of cross linking dimethacrylates (Ruyter and Svendsen, 1980; Ruyter and Oysaed, 1982). Once PMMA beads and monomer system have been mixed, beads begin to be dissolved. Increasing the time before the monomers are cured, better the beads are dissolved and more homogeneous the polymers will be (Vallittu and Ruyter, 1997). When looking at the structure of PMMA based powder–liquid resin in detail, an interphase layer between the core of the polymer bead and matrix can be found (Kawakuchi et al., 2011). Polymer structure of the interphase is semi-interpenetrating polymer network (semi-IPN) where slightly cross-linked polymer matrix has been integrated in the polymer structure of the dissolved PMMA beads. The behavior of mechanical and biological properties of acrylic resin is determined by the amount of unconverted or unreacted residual monomer present in the polymerized resin (Melilli et al., 2009). Ideally the amount of free monomer, so-called residual monomer in heat cured acrylic resin material should not exceed more than 2.2% and for autopolymerized acrylic resin material 4.5% was the maximum allowable limit according to international standards (Miettinen and Vallittu, 1997; Vallittu et al., 1998; Yilmaz et al., 2003). The residual monomer quantity when treated or immersed in ethanol showed changes in the physical properties particularly on the flexural strength and hardness and cytotoxicity caused by the leaching of the monomer in the oral cavity was reduced (Neves et al., 2013).

Chemical disinfectants have been used in order to combat bacterial contamination of the dental prosthesis (Cunegatti et al., 2008) and these disinfectants have an influence on the physicomechanical properties of the denture base resins (Shen et al., 1989). It was found that alcohol containing chemical disinfectant agents affected the flexural strength predominantly of the non-cross linked denture base resins (Asad et al., 1992). Surface roughness is another important factor which governs the adherence of the bacterial colonization (Bollen et al., 1997) and use of disinfectants for cleansing of the denture base resins affects the surface roughness significantly (Pinto et al., 2010). It is also found that an increase in the threshold of surface roughness by 0.2 μm would substantially increase the accumulation of plaque (Bollen et al., 1997) and oral organisms (Waltimo et al., 1999). Certain chemical disinfectants may cause some change in the surface roughness of the denture base polymers by crazing (Schwindling et al., 2014).

Crazing which appears as an organized crack appears on the surface of materials preferably on the thermoplastic polymers, caused by the effect of weaker Van der Walls force and a strong covalent bond. It usually occurs in those areas of the polymer material, which have a high hydrostatic tension and localized yielding resulting in the formation of microvoids (McLeish et al., 1989). Crazing can be seen by the reflection of light from the fibrils that form the backbone of the polymeric chain. Initially crazing was considered to be as cracks until it was shown that they were made of polymer interfiling interconnecting the polymer that was not deformed by the solvent (Spurr and Niegisch, 1962) and thickness of the craze was determined by the width of the groove (Kambour and Kopp, 1969). Crazing relates to the capability of solvents to dissolve the polymer and therefore factors, which influence solubility of the polymers may play a role crazing. Ethanol, which as a solubility parameter of 13 $(cal/cm^3)^{1/2}$ and denture base resins made up of polymethyl methacrylate which as a solubility parameter of 8.9–12.7 $(cal/cm^3)^{1/2}$ (Brandrup, 1975; Jacques and Wyzgoski, 1979) indicating that ethanol could dissolve or craze denture base polymer as it is already established that organic solvents which have solubility parameters as that of the polymer act as good solvent or crazing agents (Kambour, 1972). The behavior of ethanol prompted us to study on the nanomechanical (NMP) properties and its solvent tendency by varying its concentration.

Although there is some knowledge that ethanol could cause damage to the denture base polymer, there is no information at what location of the surface microstructure of multiphase denture base polymer the damage begins. Therefore, the aim of this study was to investigate solvent crazing and dissolving effect of autopolymerized and heat-polymerized denture base polymers by solvent/disinfectant with ethanol of various concentrations.

2. Materials and methods

2.1. Specimen preparation

Test specimens of size of $10 \times 10 \times 3\ mm^3$ of heat curing (Interacryl Hot, Interdent, Opekarniska, Slovenia) and autopolymerizing acrylic resin (Orthoresin, DeguDent, Hanau, Germany) was prepared and their surfaces wet ground and polished to obtain uniform smoothness. Gross nodules and