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Original article

Assessment of clasp design and flexural properties of acrylic denture base materials for use in non-metal clasp dentures

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ABSTRACT

Purpose: The purpose of this study was to investigate the possibilities of utilizing new acrylic denture base materials in resin clasps using three-point flexural tests and cantilever beam tests.
Methods: Seven non-metal clasp denture (NMCD) materials and four acrylic denture base materials were used for three-point flexural tests and six NMCD materials and three acrylic denture base materials were used for cantilever beam tests. The flexural strength, elastic modulus, and 0.05% proof stress were measured by three-point flexural tests according to International Organization for Standardization (ISO) 20795-1. And load at 0.5 mm deformation, elastic modulus were measured by Cantilever beam tests.
Results: For the three-point flexural tests, only materials that met the conditions for both flexural strength and elastic modulus were the polycarbonate Reigning N (REN) and the acrylics Acron (AC), Pro Impact (PI), Procast DSP (PC) and IvoBase High Impact (HI) which are required in ISO 20795-1, Type 3 denture base materials. And for cantilever beam tests there was no significant difference between PI and either EstheShot (ES), EstheShot Bright (ESB), REN or Acry Tone (ACT) in load at 0.5 mm deformation, and no significant difference between PI and either Lucitone FRS (LTF), ES, ESB, REN or ACT in elastic modulus.
Conclusions: The results thus suggested that some of the acrylic materials used as denture base materials may also be usable for NMCDs, and that the flexural properties of the acrylic material PI resemble those of ES, ESB and ACT, meaning that similar clasp designs may also be feasible.

1. Introduction

In recent years, increasing demand for more esthetically pleasing dental treatments has led to the widespread use of removable partial dentures that do not include metal clasps, known as non-metal clasp dentures (NMCDs) [1]. The materials used in NMCDs are mainly polyamide, polyester or polycarbonate injection-molded thermoplastic (IMTP) denture base resins, and compared with conventional acrylic

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dentures made with metal clasps, they reduce the incidence of metal allergy and provide better cosmetic appearance and fitting accuracy [2,3]. When the materials used in NMCDs are used as resin clasps, their high elasticity enables them to retain dentures by fitting into the undercut of the abutment tooth [2]. The flexural properties of resin clasps are thus closely associated with denture insertion and removal and with the transmission of stress to the abutment tooth and the mucosal surface [4,5].

Takabayashi studied six different types of IMTP denture base resins, and found that they were more resistant to fracture when compared with Acron (AC), an acrylic denture base material [6]. Hamanaka et al. also compared the flexural strength, elastic modulus and impact strength of four types of IMTP denture base resins with those of AC, and found that IMTP denture base resins had lower flexural strength and elastic modulus when compared with AC [7].

NMCD materials such as polyamide, polyester and polycarbonate have better fracture- and impact-resistance than AC, an acrylic material, but have problems with ease of grinding, denture repair, color stability and necessity of short span maintenance, and a range of novel NMCD materials are being developed in order to resolve these issues [1,6–11].

In terms of acrylic resins, conventional AC is unsuitable for NMCDs as it has high rigidity and low elasticity, making it susceptible to fracture, but a few materials are commercially available and have improved impact resistance to prevent fractures if dentures are dropped, as well as better elasticity, meaning they can possibly be used for NMCDs [12]. However, few studies have compared the physical properties of acrylic materials that could potentially be used as NMCD materials and existing materials used for NMCDs. Moreover, in clinical dentistry, the relative absence of studies into the design of resin clasps means that in the absence of scientific evidence for the design of NMCDs and clasps, individual dental laboratories are continuing to plan and produce NMCDs according to their own designs [1].

In this study, author carried out basic experiments to evaluate the flexural properties of currently used in NMCD materials and acrylic denture base materials by means of three-point flexural tests and cantilever beam tests in order to identify resin clasp materials and designs that are suitable for more widespread general use, with the aim of investigating the possibilities of utilizing new acrylic denture base materials in resin clasps.

2. Materials and methods

2.1. Test materials

The materials used in three-point flexural tests were the polyamide resins Valplast (VAL) and Lucitone FRS (LTF), the polyester resins EstheShot (ES) and EstheShot Bright (ESB), the polycarbonate resin Reigning N (REN), and the acrylic resins Acry Tone (ACT) and Acry Jet (ACJ). And for acrylic denture base materials AC, Pro Impact (PI), Procast DSP (PC) and IvoBase High Impact (HI) were used in this study.

For cantilever beam tests, materials used in the three-point flexural tests, nine materials were selected as suitable for use in NMCDs; VAL, LTF, ES, ESB, REN, ACT, AC, PI and PC. Their abbreviation, manufacturers, and forming methods are shown in Tables 1 and 2.

2.2. Fabrication of test pieces

In accordance with the manufacturer's instructions, test pieces were fabricated by using an injection molding device for IMTP denture base resins and HI. Flasks were used for the heatpolymerizing denture base resins AC and PI. The autopolymerizing denture base resin PC was fabricated in a stone mold.

The dimensions of the test pieces used for the three-point flexural tests were: length, 64 mm; width, 10 mm; and depth, 3.3 mm. The dimensions of the test pieces used for the cantilever beam tests were: length, 50 mm; width, 7 mm; and depth, 1.5 mm. Ten test pieces were fabricated for each test. Grinding was carried out under running water using #600 SiC waterproof abrasive paper, and test pieces were immersed in distilled water at 37 °C for 50 h prior to testing.

2.3. Test methods

A TG-5 kN universal testing machine (Minebea, Nagano, Japan) was used for three-point flexural testing and cantilever beam testing. The test conditions for the three-point flexural tests were those specified in ISO 20795-1, with a support span of 50 mm and a crosshead speed of 5 mm/min [13]. The test conditions for the cantilever beam tests consisted of application points simulating the upper and lower canines, and the first and second premolars, support span 7.5 mm (mean width of tooth crowns), and a crosshead speed of 2 mm/min, shown in Fig. 1a and b.

2.4. Properties assessed

2.4.1. Stress–strain curves

Stress–strain curves showing the relationship between stress and strain in the test pieces were generated from the results of three-point flexural testing.

2.4.2. Three-point flexural tests (flexural strength, elastic modulus, and 0.05% proof stress)

The flexural strength was measured at the load at fracture point for materials that had fractured and at the maximum load in the absence of fracture, and the 0.05% plastic deformation stress (0.05% proof stress) was calculated as an indicator of the elastic limit.

Flexural strength was calculated according to the following formula:

$$\text{Flexural strength} = \frac{3PL}{2bh^2}$$

where p is the maximum load (N), L is the support span (mm), b is the test piece width (mm), and h is the test piece depth (mm).

The elastic modulus was calculated according to the following formula:

$$\text{Elastic modulus} = \frac{FL^3}{4dbh^3}$$