# Experimental Compression and Traction Tests on Heat - Cured PMMA Used in Maxillary Obturator Prostheses

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*The obturators are prostheses used to close palatal defects after maxillectomy, to restore masticatory function and to improve speech, deglutition and esthetics. The most commonly used materials in manufacturing maxillary obturator prosthesis are the acrylic resins. The aim of the paper is to present experimental compression and traction tests in order to determine the material properties of Meliodent® Heat Cure produced by Heraeus Kulzer GmbH Germany. This is a two component heat curing polymer used for manufacturing fixed and removable prosthetic devices. Test results show that the average compressive strength of the samples is 94 MPa, while the average compression modulus for all resin samples tested was calculated at 716 MPa. The average ultimate tensile strength of the samples is 58.72 MPa and the average modulus of elasticity for all resin samples tested was determined to be 4213 MPa.*

*Keywords: obturator prosthesis, heat-cured PMMA, compressive strength, tensile strength*

The management of palatal defects created by surgical treatment of benign or malignant tumours, congenital malformation or by trauma is a challenging task.

The options for rehabilitation are traditional prosthetic obturator restoration or surgical reconstruction. Obturator prostheses continue to be the preferred method of rehabilitation. In addition, when surgical reconstructive procedures are performed, maxillofacial prosthetic treatment is still indicated for restoration of normal oral function in most maxillectomy patients [1].

The obturators are prostheses used to close palatal defects after maxillectomy, to restore masticatory function and to improve speech, deglutition and esthetics (fig.1). This type of prosthesis is directly influence by the defect size, location and degree of impairment [1].

This type of prosthesis can restore missing teeth as well as having a resin extension, very often at palatine level, necessary to restore proper chewing function, phonetics and breathing [1,2].

The construction of the definitive obturator will vary with the type of resection and the presence or absence of teeth. If the obturator is not properly designed and constructed, the stress on the remaining hard and soft tissues may be pathological and may lead to premature loss of abutment teeth and chronic irritation of soft tissues [1,2].

The most commonly used materials in manufacturing maxillary obturator prosthesis are the acrylic resins. These types of materials have a wide range of applications nowadays and they are continuously improved in terms of physical, mechanical and esthetical properties but they may cause some side effects regarding their biocompatibility [3].

The aim of the paper is to present experimental compression and traction tests in order to determine the material properties of Meliodent® Heat Cure produced by *Heraeus Kulzer GmbH Germany.* This is a two component heat curing polymer (powder and liquid) used for manufacturing fixed and removable prosthetic devices.

## Experimental part

### *Materials and testing methodology*

All of the test specimens were prepared using the manufacturer's recommended mixing ratio of 35g powder : 14mL liquid. The polymerization process was carried out in boiling water, initially with the heat source of for 15 min followed by 20 min of boiling. After the polymerization, the specimens were allowed to cool down slowly in the water bath.

**Table 1**

MELIODENT HEAT CURE COMPONENTS

| Powder main components | Liquid main components |
|---|---|
| *Methylmethacrylate-Copolymer* | *Methylmethacrylate* |
| | *Dimethacrylate* |

### *Compression testing*

Cylindrical compression specimens with 6 mm diameter and 12 mm height (according to ASTM F451) were obtained (fig. 2). To obtain the final shape, all samples were polished with 600 grit abrasive paper until the surface was free of mold marks [4]. A total of 5 cylinders were cast using this method.

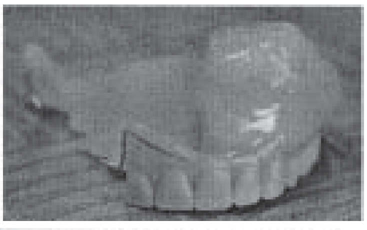

Fig. 1. Maxillary obturator prosthesis made from heat-cured PMMA

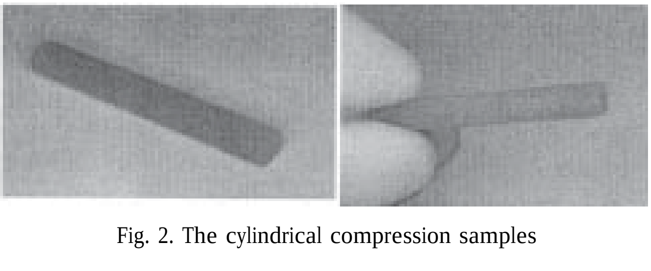

Fig. 2. The cylindrical compression samples

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The specimens were subjected to a compression test on a 5kN Zwick/Roell traction-compression machine. Following the guidelines specified in ASTM F451 (Standard specification for acrylic bone cement) [4], a test speed of 20 mm/min was used, while test conditions were room temperature (23°C) and 20% relative humidity.

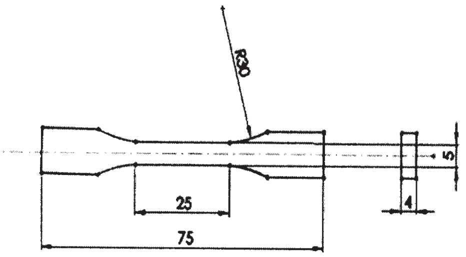
Elastic modulus, Poisson's ratio and compressive strength were calculated. To determine Poisson's ratio, the test speed was set to 1 mm/min, according to ASTM E132-04 (Standard test method for Poisson's ratio at room temperature). Samsung SIR-4160 high speed camera and SigmaScan Pro image processing software were used in order to measure the transverse strain [4].

*Traction testing*

After the polymerization and cooling down in the water bath, the acrylic resin was inserted during into a silicon mold with specified dimension according to ISO 527 (fig. 3). To obtain the final shape, all samples were polished with 600 grit abrasive paper in the longitudinal direction until the surface was free of mold marks. The specimens containing defects larger than 1 mm were excluded from the study. A total of 5 test samples were obtained using this method.

The specimens were subjected to a tensile test on a hydraulic machine (Walter+Bai LFV-10kN - fig. 4) with a distance between grips of 35 mm. According to ISO 527, the testing speed was set at 1 mm/min. Special fixing devices were manufactured to ensure that the hydraulic grips don't produce critical stress areas to test specimens (fig 4.).

The tensile strength (stress at failure), % elongation (strain at failure), and elastic modulus were calculated for each specimen.



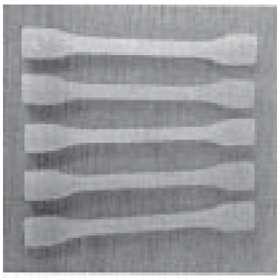


Fig. 3. Test specimen dimensions according to ISO 527 (up) and obtained test samples (down)

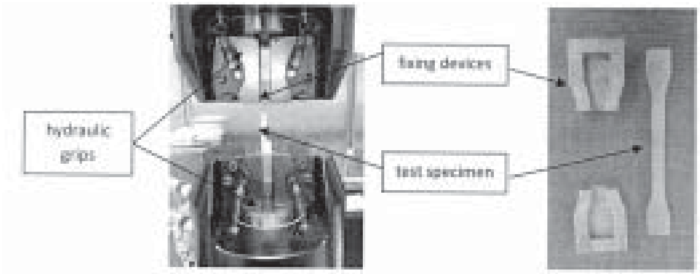


Fig. 4. Hydraulic machine model Baiag Walter LFV-10kN and fixing devices

## Results and discussions

*Compression testing*

The load–longitudinal displacement curves of all resin samples tested exhibited similar linear elastic regime (load up to 2575 - 2734 N corresponding to 4.51 – 4.67 mm displacement), followed by yielding and a local maximum (2527 - 3093 N applied load, corresponding to 4.51 – 4.67 mm displacement).

Test results show that the average compressive strength of the samples is 94 MPa (range: 87.02 – 108.83 MPa). The compressive strength values obtained exceeds the minimum value of 70 MPa specified in ASTM F451, as showed in Fig 6. The curves presented in figures 4 and 5 were obtained by means of interpolation of the individual results. The average compression modulus for all resin samples tested was calculated at 716 MPa (range: 622 – 980 MPa).

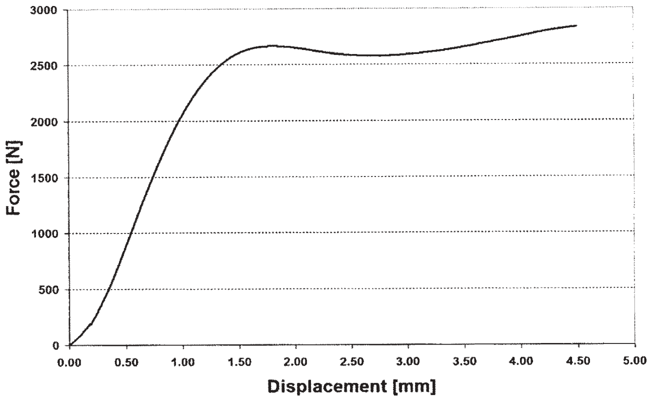


Fig. 5. Force – displacement curve

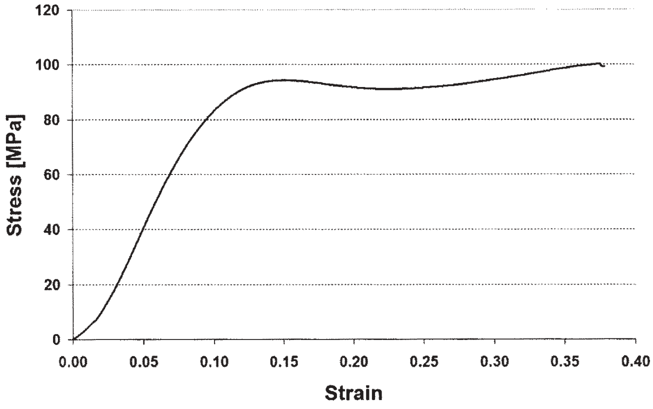


Fig. 6. Compressive strain-stress curve

In order to determine Poisson's ratio, the average longitudinal strain, $\varepsilon_l$, and the average traverse strain, $\varepsilon_t$, measured by the high speed camera and SigmaScan Pro image processing software were plotted against the applied force [4]. Poisson' ration was calculated using the following equation:

$$\nu = \frac{\frac{d\varepsilon_t}{dP}}{\frac{d\varepsilon_l}{dP}} = 0.29$$

where:

$d\varepsilon_t$ - is the change in transverse strain,
$d\varepsilon_l$ - is the change in longitudinal strain,
dP - is the change in applied load.

*Tension testing*

The tensile stress–strain curves of all resin specimens tested exhibited similar linear elastic regime (load up to 943 - 969 N corresponding to 3.12 – 3.30 mm

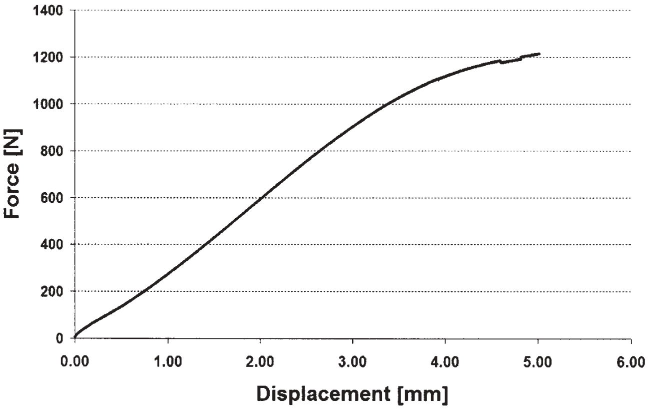


Fig. 7. Force – displacement curve

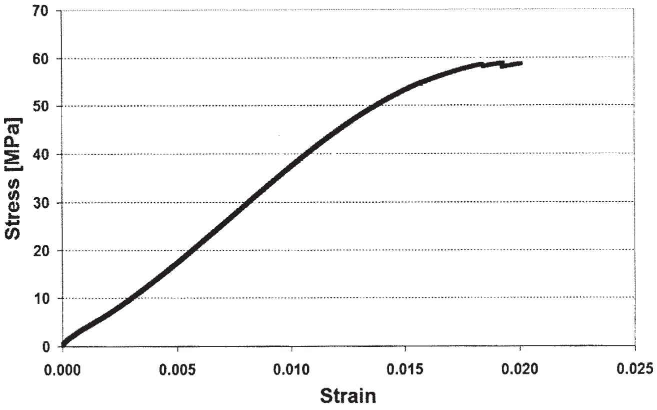


Fig. 8. Tension strain-stress curve

displacement), followed by brittle fracture (1112 - 1243 N applied load, corresponding to 3.91 – 4.84 mm displacement).

The curves presented in figure 6 and 7 were obtained by means of interpolation of the individual results.

Test results show that the average ultimate tensile strength (fig 8.) of the samples is 58.72 MPa (range: 56.05 – 61.4 MPa). The average specific strain of the samples is 1.79% (range: 1.56 % – 2.01%). The longitudinal modulus of elasticity was calculated for each sample. The average modulus for all resin samples tested was determined to be 4213 MPa (range: 3885 - 4450 MPa).

## Conclusions

The experimental compression and traction test presented in this paper prove to be a useful method to determine the mechanical properties of acrylic resins used nowadays in manufacturing various types of dental prostheses, including obturator prostheses. Within the limitation of this study the results are comparable with the data found in the literature for pure heat cured acrylic resin [5,6]. Further tests need to be made on reinforced acrylic resins since the previous studies found in the literature showed different mechanical properties in this cases [5,6]. Another type of material that shows interest and need to be tested is represented by the nylon resins also used in munafacturing dental prosteses [7].

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