Thermoplastic Materials Used for Fabrication of Maxillary Obturator Prostheses

Experimental compression and traction tests

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Maxillary obturator prostheses are dental devices used to close palatal defects created by surgical resection of different type of tumors, congenital malformation or trauma. The most popular material used for denture fabrication is the polymethyl methacrylate (PMMA). In recent years thermoplastic resins has attracted attention as a denture base material. This paper presents experimental compression and traction tests of Vertex™ThermoSense from Vertex-Dental B.V. Vertex™ThermoSense is a thermoplastic material based on a compounded mixture of Polyamide and pigments used in the fabrication of removable full and partial dental prostheses. Test results show that the average compressive yield strength of the samples is 60.18 MPa. The result of the tensile test showed an average of 49.4 MPa yield strength. Vertex™ThermoSense has a very good average of the yield strain of 10%. The average of Young modulus is 1050 MPa.

Keywords: obturator prosthesis, thermoplastic materials, compressive strength, tensile strength

Polymethyl methacrylate (PMMA) is still the most popular material used for denture fabrication since its introduction in 1937 [1]. It has the advantages of good esthetic characteristic, low water absorption and solubility, adequate strength, low toxicity, easy repair and simple processing technique. PMMA also has some problems regarding polymerization shrinkage, weak flexural, lower impact strength and low fatigue resistance [2-4]. Considering the fact that these types of materials have a wide range of applications, various efforts have been taken in order to improve the physical, mechanical and esthetical properties, including addition of metal wires or plates, fibers, and modification of chemical structure [5-9]. Also, this type of material can cause some side effects regarding their biocompatibility [10]. In recent years, thermoplastic resins or nylon polymers has attracted attention as a denture base material. Nylon is a generic name for certain types of thermoplastic polymers belonging to the class of polyamides. Polyamide resin was first proposed as a denture base in the 1950s [11].

Thermoplastic resins can also be used for manufacturing obturator prostheses, which are a variation of a full or partial dental prosthesis used in the field of maxillofacial surgery for rehabilitation of palatal defects after maxillectomy (Fig. 1). The main role of this type of prosthesis is to restore masticatory function and improve speech, deglutition and esthetics [12].

This paper presents experimental compression and traction tests of Vertex™ThermoSense from *Vertex-Dental B.V.* Vertex™ThermoSense is a thermoplastic material based on a compounded mixture of Polyamide and pigments used in the fabrication of removable full and

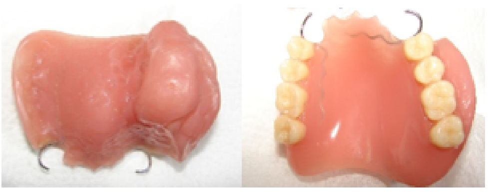

Fig. 1.

Fig. 1. Maxillary obturator prostheses

partial dental prostheses. Also, we compare the results with PMMA, previously tested and published.

Experimental part

Materials and testing methodology

The technique for Vertex™ ThermoSens is based on injection technique. The technique can be done with an automatic or manual injection machine. The preparations of the model and flask are according to the standard procedures of the dental technique.

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 processing on the lathe. A total of 8 cylinders were cast using this method.

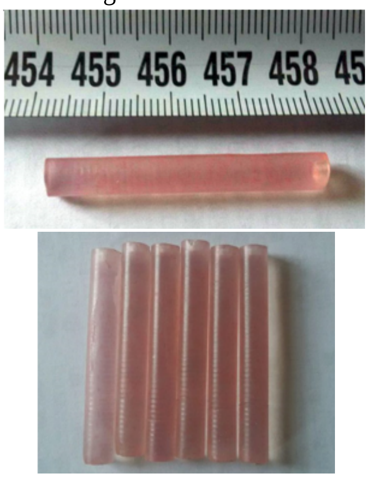

Fig. 2. The cylindrical compression samples

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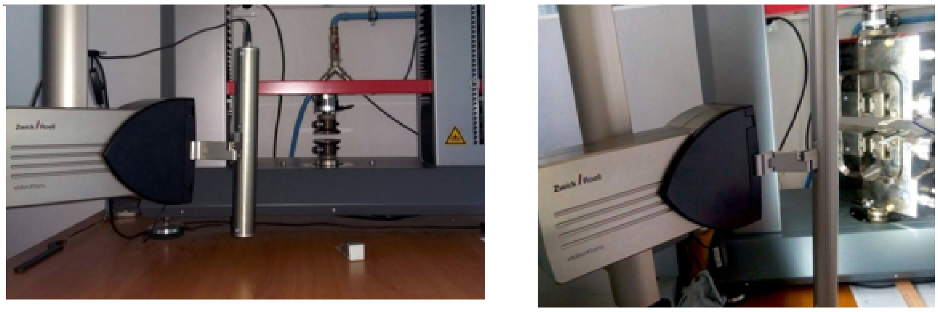

Fig. 3. Zwich / Roell traction-compression machine

The specimens were subjected to a compression test on a 5kN Zwick/Roell traction-compression machine (fig. 3). Following the guidelines specified in ASTM F451 (Standard specification for acrylic bone cement), a test speed of 1 mm/min was used, while test conditions were room temperature (23C) 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 E13204 (Standard test method for Poisson's ratio at room temperature). Video Extensometer Zwick/Roelland Sigma Scan Pro image processing software was used in order to measure the transverse strain.

Traction testing

Test specimens were obtained with specified dimensions according to ISO 527. 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 (fig. 4).

The specimens were subjected to a tensile test on a 5kN Zwick/Roell traction-compression machine (fig. 3).

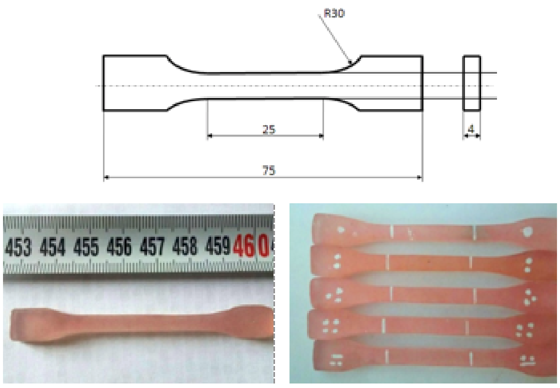

Fig. 4. Test specimen dimensions according to ISO 527 and obtained test samples

According to ISO 527, the testing speed was set at 1 mm/min.

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

Results and discussions

Compression testing

The load–longitudinal displacement curves (fig. 5) of all resin samples tested exhibited similar linear elastic regime (load up to 1324 - 1408 N corresponding to 1.4 – 1.6 mm displacement), followed by yielding and a local maximum (1929 - 2007 N applied load, corresponding to 4.9 – 5.2 mm displacement).

In table 1 are presented the principal characteristics of the material resulting from compression tests.

Test results show (fig. 6) that the average compressive yield strength of the samples is 60.18MPa (range: 57.592 – 61.37MPa). The average compression modulus for all resin samples tested is 546MPa (range: 506 – 562MPa).

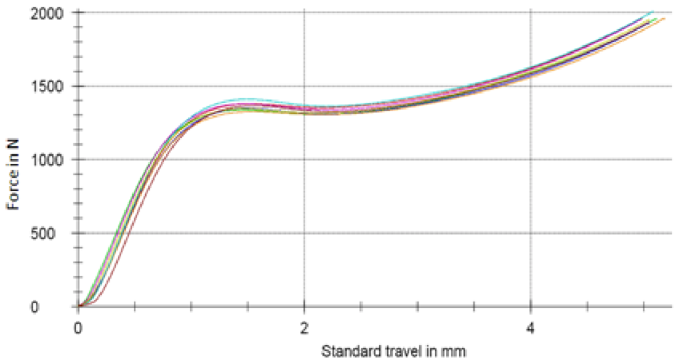

Fig.5. Force-displacement curve

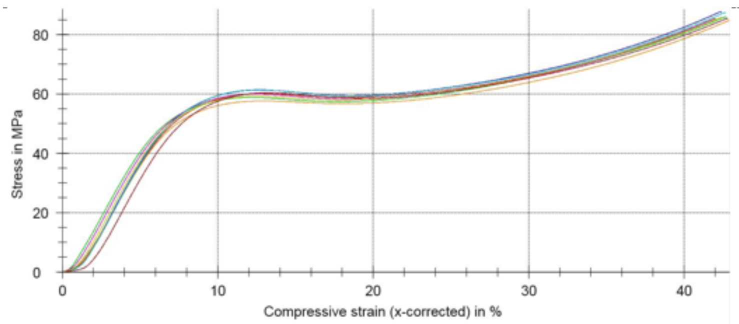

Fig. 6. Compressive strain-stress curve

Table 1
COMPRESSION TEST RESULTS

Specimen designation	Compression Modulus E_c[MPa]	Force F [N]	Yield strength σ_y[MPa]	Yield strain ε_y[%]	Area A [mm^2]
Sample 1	555	1387	60.46	13	22.94
Sample 2	650	1335	58.73	12	22.73
Sample 3	531	1347	61.28	12,5	21.98
Sample 4	562	1324	57.59	12,5	22.99
Sample 5	506	1377	59.89	12,5	22.99
Sample 6	514	1408	61.37	13	22.94
Sample 7	550	1345	59.27	12,5	22.69
Sample 8	506	1366	60.41	13,5	22.61
Statistics	**546**	**1368**	**60.18**	**12,7**	**22.73**

In order to determine Poisson's ratio, the average longitudinal strain, ε_l, and the average traverse strain, ε_t, measured by the video extensometer and SigmaScan Pro image processing software were plotted against the applied force. Poisson' ration was calculated using the following equation:

$$\nu = \frac{\frac{d\varepsilon_t}{dP}}{\frac{d\varepsilon_l}{dP}} = 0.09$$

where:

ε_l – is the change in longitudinal strain
ε_t – is the change in transversal strain
dP –is the change in applied load.

Tension testing

The tensile stress–strain curves (fig. 7 and fig. 8) of all resin specimens tested exhibited similar linear elastic regime (load up to 1020 - 1080 N corresponding to 3.12 – 3.30 mm displacement), followed by yielding.

In table 2 are presented the principal characteristics of the material resulting from tension tests.

Test results show that the average of the yield strength (fig. 8) of the samples is 49.4MPa (range: 45.9 – 51.9MPa). The average yield strain of the samples is 10% (range: 8.9 % – 11%). The longitudinal modulus of elasticity was calculated for each sample. The average modulus for all resin samples tested was determined to be 1050MPa (range: 985–1160MPa).

Average stress at break is 48.7 and the average of nominal strain at break is 130%.

When comparing the results with the ones obtained for Heat-Cured PMMA (Meliodent® Heat Cure) [13], we observe that the average compressive yield strength of Vertex™ThermoSense is 60.18 MPa compared to 94 MPa for Meliodent® Heat Cure. Also, the result of the tensile test showed an average of 58.72 yield strength for Meliodent® Heat Cure compared to 49.4 MPa for Vertex™ThermoSense. Vertex™ThermoSense has a very good average of the yield strain of 10% (range 8.9 – 11%) compared to 1.79% (range: 1.56 % – 2.01%) for Meliodent® Heat Cure. Differences were observed between the two averages of Young modulus:4213 MPa for Meliodent® Heat Cure and 1050 MPa for Vertex™ThermoSense.

According to this comparison it seems that thermoplastic materials have inferior compression and tensile characteristics but have a much better yield strain.

Table 2
TENSION TEST RESULTS

Specimen designation	Tensile Modulus E [MPa]	Maxim Force F_{max}[N]	Yield strength σ_y[MPa]	Yield strain ε_y[%]	Stress at break σ_b[MPa]	Nominal strain atbreak ε_{tb}[%]
Sample 1	1020	1020	45.9	10	40.1	97
Sample 2	1160	1080	51.9	8.9	54.2	130
Sample 3	986	1070	49.6	11	50.9	150
Sample 4	1110	1040	48.9	11	43.4	130
Sample 5	985	1100	50.9	11	54.9	150
Statistics	1050	1062	49.4	10	48.7	130

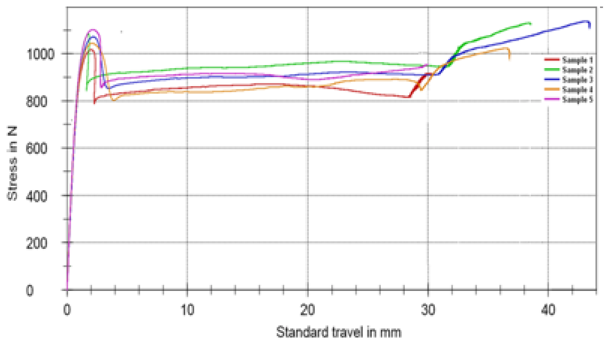

Fig. 7 Force-displacement curve

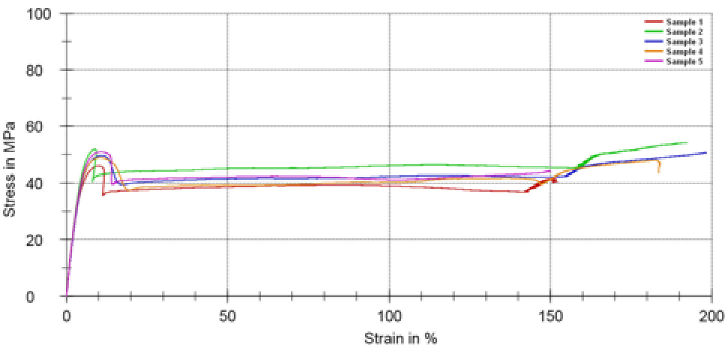

Fig. 8 Tension strain-stress curve

Conclusions

This paper presents tensile and compression experimental tests to determine the mechanical properties of thermoplastic materials used for fabrication of maxillary obturator prostheses. The methods we have used prove to be useful.

Although the tensile strength and the strength in compression of thermoplastic materials are relatively low compared to Heat-Cured PMMA, previously tested and published, they demonstrate great ductility.

It was suggested in literature that by adding glass fibers, their mechanical properties could be increased [14].

The use of these materials has some advantages regarding their esthetic and degree of retention [14].

Therefore, selection of thermoplastic materials for manufacturing maxillary obturator prostheses should take in consideration the advantages and disadvantages of these materials and require adaptation for each clinical case.

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