original articles

scanning electron microscopy or optical coherence tomography for the evaluation of the glass fiber reinforced acrylic resin?

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rezumat

Obţinerea unor materiale rezistente şi estetice sunt criterii unanim acceptate în medicina dentară actuală. Obiectiv: Evaluarea facilă a interfeţei răşină acrilică/fibre de sticlă. Materiale şi metode: Probele în număr 36 au fost realizate din răşină acrilică termopolimerizabilă (Meliodent -Kulzer); 12 au fost armate cu fibre de sticlă unidirecţionale (Stick - Stick tech, Finland); 12 cu plasă din fibre de sticlă (Stick net - Stick tech, Finland) iar 12 nu au fost armate (control); epruvetele au fost realizate conform standardului ISO 1567: 1999 (E). Probele au fost analizate folosind tomografia optic coerentă (OCT) în cadrul Department of Applied Optics, School of Physical Sciences, University of Kent, Canterbury, UK. Analiza prin microscopie electronică cu baleiaj s-a realizat folosind un microscop electronic cu baleiaj (SEM, TESLA BS 343 A (Cehia) din cadrul ISIM Timişoara – Departamentul de încercări de materiale. Probele au fost metalizate în prealabil cu foaie de aur (Au) metalizarea realizându-se în vid. Rezultate: Imaginile SEM au fost obţinute la măriri de 48× 55µ, 120× 55µ, 240× 55µ, 480× 55µ, pentru fiecare dintre probă. Imaginile OCT au fost obţinute prin investigaţii realizate la 670 nm, şi 1300 nm. Pentru fiecare probă investigată la 670 nm s-au realizat minim 61 de sliceuri per stick, respectiv pentru 1300 nm minim 100 sliceuri per stick. Concluzii: Ambele metode de investigaţie optică permit evidenţierea în bune condiţii a interfeţei răşină acrilică/armatură din fibre de sticlă. SEM însă este mult mai greoi de pe faţa de OCT care permite vizualizarea amănunţită şi facilă a interfeţelor. Cuvinte cheie: răşină acrilică, fibre de sticlă, tomografie optic coerentă, microscopie electronică cu baleiaj.

abstract

Aesthetics and strength are two major criteria for dental materials today. Objective: Easy evaluation of the bond between acrylic resin and glass fibers. Materials and methods: Pre-impregnated woven E-glass fibres (Stick® Net, Stick Tech Ltd Oy) and unidirectional pre-impregnated E-glass fibres (Stick˘TM) were used to reinforce a conventional heat-curing denture base resin (Meliodent, Heraeus Kulzer GmbH&Co.KG) - ISO 1567:1999 (E). The samples were 12 Stick reinforced, 12 Stick net reinforced (Stick tech, Finland) and 12 were un-reinforced (control). Optical coherence tomography (OCT) investigation was performed in the Department of Applied Optics, School of Physical Sciences University of Kent, UK. SEM micrographs of the fractured specimens were taken using a SEM microscope (TESLA BS 343 A) in the Department of Materials Testing - ISIM Timişoara, Romania. The samples were in vacuum gold plated. Results: The SEM images were taken at 48× 55µ, 120× 55µ, 240× 55µ, 480× 55µ magnifications for each sample. The OCT micrographs were taken at 670 nm and 1300 nm. The penetration depth is in micron range up to 2 mm. For each sample investigated at 670 nm, 61 de sliceuri per stick, and for each sample investigated at 1300 nm, minimum 100 sliceuri per stick were taken. Conclusions: Both methods are useful for the bond in between acrylic resin and glass fibers evaluation. SEM is more laborious than OCT which is able to obtain many precise images in steps up to 1 µ. Key words: acrylic resin, glass fibers, optical coherence tomography, scanning electron microscopy

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Introduction

Aesthetics and strength are two major criteria for dental materials today. Acrylic resin proved that it is a useful, competitive and affordable material for all the patients wearing partial or complete removable dentures. But also these materials cannot fulfill all the hardness requirements. Many studies have proved that glass fiber reinforcements are useful in reinforcing heat curing denture base acrylic resin. 1-13 Some of the clinical studies analyzed the interface acrylic resin glass fibers using scanning electron microscopy (SEM). 1,5,13 The optical coherence tomography (OCT) is a new optical investigation method and it has been recently used in some studies. 4,5,14
Objective. Easy evaluation of the bond between acrylic resin and glass fibers.

MATERIALS AND METHODS

Pre-impregnated woven E-glass fibres (Stick® Net, Stick Tech Ltd Oy) and unidirectional pre-impregnated E-glass fibres (Stick™) were used to reinforce a conventional heat-curing denture base resin (Meliodent, Heraeus Kulzer GmbH&Co.KG) - ISO 1567: 1999 (E). The samples were 12 Stick reinforced, 12 Stick net reinforced (Stick tech, Finland) and 12 were un-reinforced (control).

OCT investigation was performed in the Department of Applied Optics, School of Physical Sciences University of Kent, UK. The OCT micrographs were taken at 670 nm and 1300 nm. The penetration depth is in micron range up to 2 mm. For each sample investigated at 670 nm, 61 de slices per stuck were taken and for each sample investigated at 1300 nm, minimum 100 slices per stuck were taken.

SEM micrographs of the fractured specimens were taken using a SEM microscope (TESLA BS 343 A) in the Department of Materials Testing - ISIM Timisoara, Romania. The samples were in vacuum gold plated. The SEM images were taken at 48× 55µ, 120× 55µ, 240× 55µ, 480× 55µ magnifications for each sample (Fig. 1).

RESULTS

The cross section scanning electron image of unidirectional glass fibers (Stick) reinforced denture base resin taken at a magnification 240 ×, 55 µm (Fig. 2) reveals a good bond between the glass fiber and the acrylic resin but the same magnification in other images reveals some problems in between the glass fibers and also in between the glass fibers and the acrylic resin (Fig 3). The magnification 480 ×, 55 µm reveals in some images a good bond between the unidirectional glass fibers and the acrylic resin (Fig. 4) but also some voids between the glass fibers and between the glass fibers and the acrylic resin as well (Fig. 5). The scanning electron images taken on glass fiber net reinforced samples (240 ×, 55 µm and 24 ×, 55 µm) shows us a fragile fracture on the cross-section and also the reduced amount of glass fibers included in these samples (Fig. 6 a, b).
Figure 5. Cross section SEM images of unidirectional glass fibers reinforced acrylic resin (480 ×, 55 µm) - presence of some voids.

Figure 6. SEM images of glass fiber net reinforced acrylic resin – fragile fracture section (240 ×, 55 µm-a; 24 ×, 55 µm-b)

Figure 7. OCT investigation - unidirectional glass fiber reinforcement/ acrylic resin - 670 nm.

The images that have resulted after the 670 nm investigation shows us some small bonding defects in between the unidirectional glass fibers but a very good bond between the glass fibers and the acrylic resin (Fig 7). In the investigation taken at 670 nm for the samples reinforced with glass fiber net we can observe some voids between the acrylic resin and the glass fiber net probably due to a poor manipulation of the reinforcement (Fig 8 a, b). Investigations done using the 1300 nm scanning also reveal small defects between the acrylic resin and the glass fibers (Fig. 9).

Figure 8. OCT investigation - glass fiber net reinforcement /acrylic resin - 670 nm.

Figure 9. 1300 nm OCT investigation; small defects in-between the glass fibers; good bond between the glass fibers/acrylic resin; no. 100 from 100 slices (sample no. 4)

The investigation taken at 1300 nm has also a confocal microscope that allows comparative real-time evaluation of the first slices. This system allows us to obtain also 3D reconstructions of the samples, were we can visualize the porous structure of the heat cured acrylic resin and also the structure of the glass fiber reinforcement (Fig. 10 a, b).

DISCUSSIONS

The scanning electron microscopy is a type of electron microscopy that images the sample surface by scanning it with a high-energy beam of electrons in a raster scan pattern (the rectangular pattern of image capture and reconstruction). It is a well known method used in dentistry for different interfaces
evaluation\textsuperscript{15-19} as well as for the evaluation of the glass fibers reinforced removable dentures by many researchers.\textsuperscript{1,7,11-14,18,20-23} But this method is an invasive one. Fractures of the samples can appear when in vacuum plating thus the results are going to be wrong. All the samples have to be metal plated and this is a problem concerning the samples which are destroyed in the end. On the contrary, the optical coherence tomography is a non invasive method and allows us to receive a large amount of digital images. Kim Y, Choi ES, Woosep K et al showed that OCT is a modern imagistic evaluation tool, better then SEM.\textsuperscript{24}

The optical coherence tomography is an optical signal acquisition and processing method allowing extremely high-quality, micrometer-resolution, and three-dimensional images from within optical scattering media. The studies using OCT for evaluating the glass fibers acrylic resin interface\textsuperscript{16-19} revealed the advantages of this investigation method as well.

The present study also emphasizes that OCT is a very competitive tool for the evaluation of bonds between acrylic resin and glass fibers, better than scanning electron microscopy.

**CONCLUSIONS**

Within the limits of this study the following conclusions can be drawn:
1. Both methods are useful for the evaluation of the bond between acrylic resin and glass fibers.
2. Scanning electron microscopy is more laborious than optical coherence tomography which is able to provide many precise images in steps up to 1 μ.

**REFERENCES**


