Time Domain Optical Coherence Tomography Evaluation of Polymeric Fixed Partial Prostheses

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Polymeric fixed partial prosthesis represents an important part of the prosthetic treatment. Their presence in the oral cavity could lead to fracture them and to alter the final prosthetic treatment. Time Domain Optical Coherence Tomography can be used as a noninvasive evaluation method and 3D reconstructions which could generate a real forecast on those prosthesis in the oral cavity environment.

Keywords: polymeric fixed partial prosthesis, optical coherence tomography, non invasive method, material defect

A fixed partial prosthesis should be well fabricated in order to maintain the health of the pulpal, periodontal and dental tissues from the time of tooth preparation until delivery of the definitive prosthesis [Gegauff and Holloway, 2001]. In order to achieve optimal tissue health the dental prosthesis must have good marginal fit, proper contour and smooth surfaces. The longer the period of time in which a dental prosthesis is in use the better fabricated it must be in order to ensure for proper tissue health [Shillinburg et al, 1997]. According to Rosenstiel [2001] the biologic category should include pulpal and tooth fracture protection, maintenance of periodontal health and tooth position and occlusal compatibility. Gingival health is very important in fixed partial prosthesis where the master impressions and cementation are to be completed. Imflamed gingival tissues can make these moisture sensitive procedures very difficult. As a result, many authors suggested the use of interim prosthesis [Vahidi, 1987; Shillimburg et al, 1997, Gegauff and Holloway, 2001, Gratton and Aquilino, 2004]. If any of these are not properly fabricated and maintained, inflammation and recession of the free gingival margin can occur [Waerhaug and Zander, 1957; Donaldson, 1973, Burns et al, 2003]. A polymeric fixed partial prosthesis should be well fabricated in order to withstand stresses produced during mastication and prevent displacement [Gegauff and Holloway, 2001, Gratton and Aquilino, 2004]. Multiple authors have studied the amount of stress and force a fixed prosthesis must withstand while in function. The average chewing functional load per tooth on a fixed prosthesis ranged 2 – 22 N with an increase in the load of 15 % during swallowing [Bates et al, 1976; DeBoever et al 1978, Neill et al, 1989].

However, other investigators found that this load had a higher range of 20 – 90 N [Anderson, 1956, Gibbs et al, 1981]. The chewing frequency in humans has been found to be about 1.25 to 2 Hz [Carlson 1974, Neill and Howard, 1988] with a definitive dental prosthesis required to undergo 3×10^6 to 10^7 load cycles in a 5 – 15 year lifetime depending on the author [Bates et al 1976, Wiskott et al 1994]. Stresses on polymeric prosthesis occur mostly from masticatory forces. The polymeric prosthesis must be able to withstand functional forces as mastication without fracturing. The polymeric fixed partial prosthesis used in this paper were made from polymethyl methacrylate. The polymerization process that turns methyl methacrylate into polymethyl methacrylate or PMMA is credited to German chemists, Fittig and Paul, in 1877. The next couple of decades saw minimal use of PMMA until the early 1930's when a german company began to produce PLEXIGLAS [Herman, 1985]. In 1937, Dr. Walter Wright was the first to describe PMMA's use with denture fabrication. The use of PMMA in fixed partial prosthesis appeared in the literature in 1940 for the fabrication of inlays, crowns and fixed partial dentures [Peyton 1975, Rueggeberg, 2002]. Auto-polymerising PMMA appeared in the late 1940's and was shortly introduced into clinical use in dentistry for provisional fixed prostheses [Devlin, 1984]. Since its appearance, PMMA quickly became and currently is the most frequently used material for provisional fixed partial prosthesis [Kaiser 1985, Christensen 1997]. Some current product names for PMMA include Caulk temporary bridge resin [Dentsply], Vita VM CC [Vident] and Jet [Lang Dental].

Optical coherence tomography (OCT) is a noncontact imaging modality that provides cross-sectional images of biological structures, in-vivo and non-invasively, by detecting light backscattered from tissue. In ophthalmology, OCT is primarily used to image the retina and optic nerve, in order to detect and monitor a variety of retinal diseases and optic neuropathies. The use of OCT has increased in recent years, due to software and hardware improvements [1-4] rapid collection of high-resolution, three-dimensional (3D) datasets, and clinical studies confirming the reproducibility [5-11] and disease-discriminating capability [12-17]. OCT is now becoming accepted as a reliable tool for clinicians assessing dental structure that allow the measurements.

Contrast agents are substances designed to alter the detected signal of a biological image in a way that allows the region containing the agent to be discernible. For example, in X-ray imaging, high atomic number elements such as iodine are routinely used to improve delineation of blood vessels and organs by the absorption of incident X-rays[18]. Medical imaging techniques such as X-ray, magnetic resonance imaging (MRI), computed tomography and ultrasound each may be augmented by contrast agents approved by the Federal Drug Administration (FDA) [18,- 21]. Gold nanoparticles can be nanoengineered to be highly backscattering at the near infrared (NIR) wavelengths used in OCT imaging.antibody conjugation [22, 23]. However there are some papers related to application of OCT in Dentistry [24- 29].

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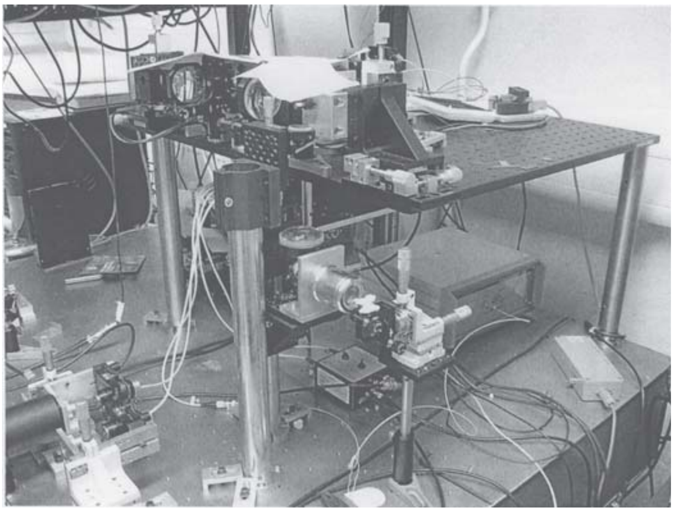

Fig. 1. Optical coherence tomography system architecture.

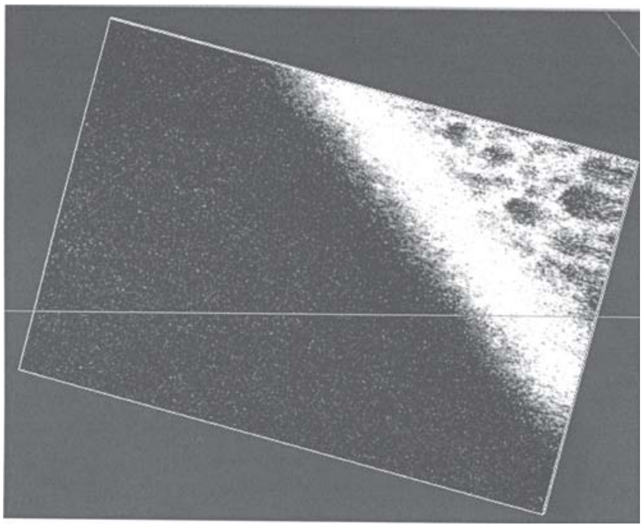

Fig. 2. 2D evaluation (C scan) of the investigated area; on the 3D reconstruction it is possible to evaluate the entire volume of the polymer.

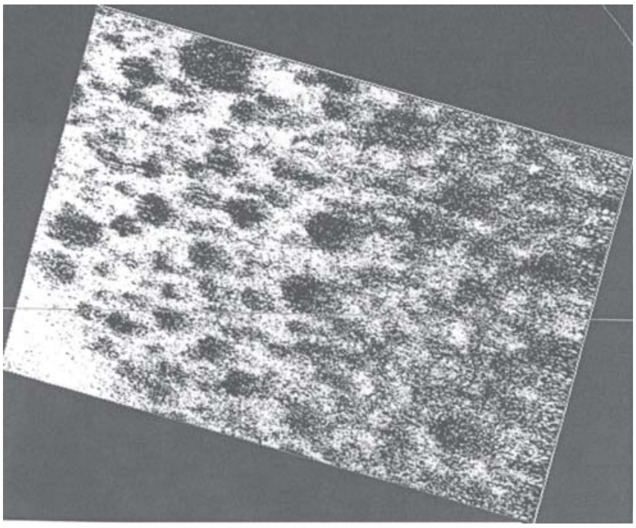

Fig. 3. 2D investigation (C scan) inside the polymer structure (slide 78 from 350, zoom 8 degree, aprox. 0.56 mm inside the structure); note the porous aspect of the material.

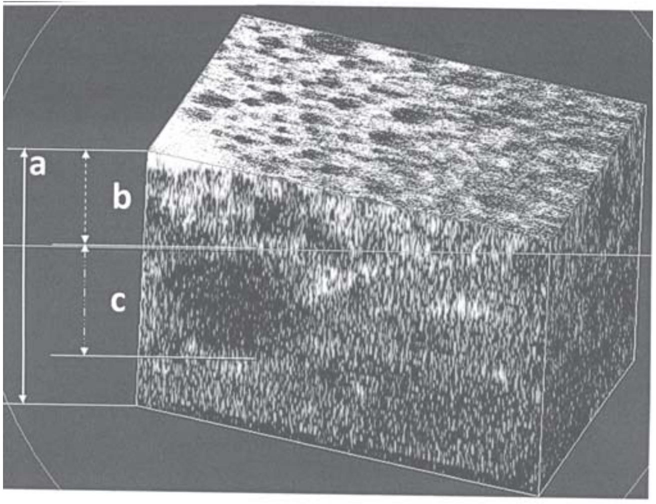

Fig. 4. Aeric inclusion observed on the B scan evaluation inside the polymeric structure at aprox. 0.9 mm from the surface (b); the vertical dimension of the defect is aprox. 1.1 mm (c) and the total vertical dimension of the polymer structure is 2.5 mm (a).

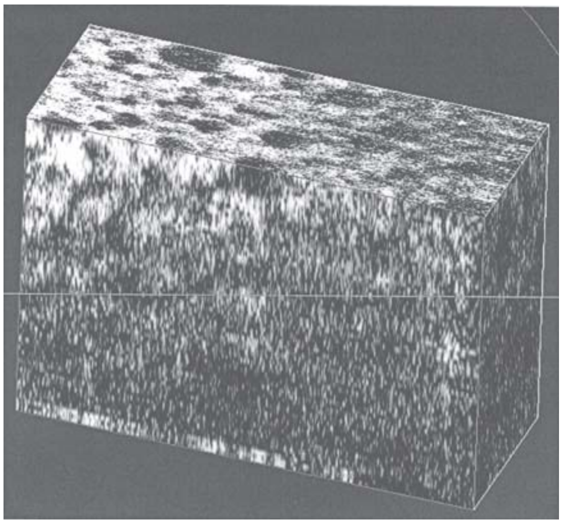

Fig. 5. B scan evaluation showing no other significant material defects inside the polymer structure.

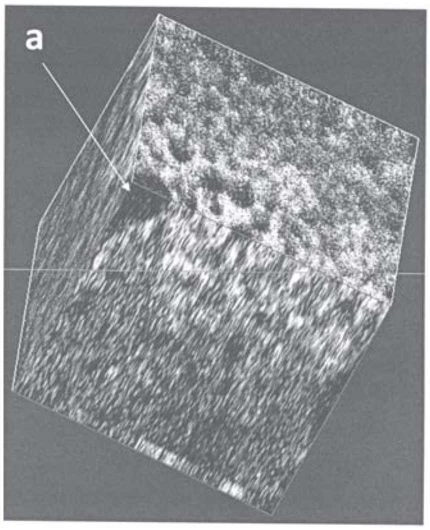

Fig. 6. B scan and C scan showing a material defect (a) at aprox. 0.18 mm from the surface; this defect goes deep inside the structure aprox. 0.45 mm.

Experimental part

34 fixed partial prosthesis were obtained from PMMA by conventional procedure. All the samples were investigated by Time Domain Optical Coherence Tomography as a non invasive method. The scanning procedure was from occlusal to cervical areas of the prosthesis on the vestibular face of the structures. The scanning times were 40 to 50 s for 350 slices per sample. The targeted areas were

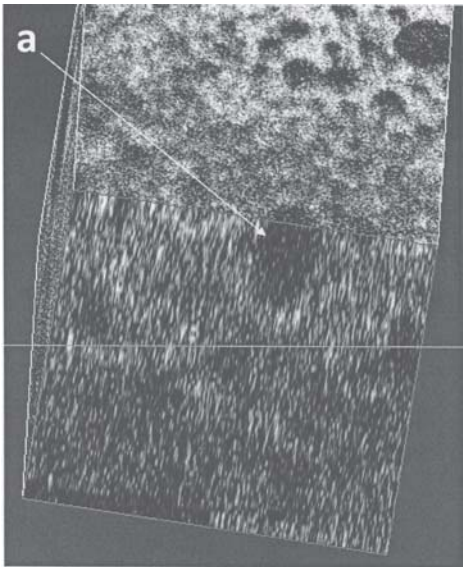

Fig. 7. B scan and C scan showing a material defect (a) at aprox. 0.35 mm from the surface; this defect goes deep inside the structure aprox. 0.53 mm.

identified with a confocal channel working at 970 nm. The zoom scan was off; the scanning angle was at 18 degree. The 2D and 3D images results were obtained and were evaluated in order to observe the internal structure of the prosthesis. The aim of this study was to observe the eventual material defects that could lead to fracture lines in the entire prostheses structure and to the failure of the prosthetic treatment.

Results and discussions

All the samples were investigated by Optical Coherence Tomography working in Time Domain combining with a confocal channel in order to evaluate the structure of the polymeric prosthesis (fig. 1). The confocal channel was used in order to point the area of the investigations in surface and that with the OCT the investigations were performed deeper in the polymeric material. The results show that there are no defects at the surface (fig. 2). Inside the polymeric material the OCT revealed the porous aspect of the dental materials (fig. 3). In order to have a better evaluation of the polymer structure a 3 D reconstruction was performed. The aeric inclusions were spotted in the occlusal area and that the magnitudes of those defects were evaluated (fig. 4 - 7). None of these defects were surface open.

Conclusions

In conclusion, noninvasive evaluations methods , especially OCT working in Time Domain mode, has a great capability to evaluate the internal structure of the polymeric material used for the fixed partial prosthesis considered. Most of these defects were localized in the occlusal areas of the fixed partial prosthesis and than could lead to fractures and failures of the prosthetic treatment. This is why a noninvasive evaluation of these prosthesis, such as optical coherence tomography, is need it to be done before insertion in the oral cavity.

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