JOURNAL OF THE MECHANICAL BEHAVIOR OF BIOMEDICAL MATERIALS 49 (2015) 290–299

Available online at www.sciencedirect.com

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Research Paper

# On the mechanical integrity of retrieved dental implants

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ARTICLE INFO

*Article history:*
Received 8 February 2015
Received in revised form
11 May 2015
Accepted 17 May 2015
Available online 25 May 2015

*Keywords:*
Dental implants
Surface treatment
Retrieved dental implants
Mechanical complication
Full fracture
Crack-like defects

ABSTRACT

The objective of this work is to investigate the potential state of mechanical damage in used, albeit mechanically intact, dental implants, after their retrieval from the oral cavity because of progressive bone loss (peri-implantitis).

100 retrieved dental implants were characterized with no medical record made available prior to the analysis. The implants' composition, dimensions, and surface treatments were characterized using energy dispersive X-ray analysis and scanning electron microscopy (SEM-EDX). Each implant was thoroughly examined for signs of mechanical defects and damage.

The implants represent a random combination of two materials, titanium alloy (Ti–6Al–4V) and commercially pure titanium (CP-Ti), surface treatments and geometries. Two kinds of surface defects were identified: crack-like defects and full cracks that were arbitrarily divided according to their length and appearance. We found that over 60% of the implants contained both crack-like defects and full cracks. In the retrieved sample, we observed that the CP-Ti implants contained more defects and cracks than the Ti–6Al–4V ones. For the various surface roughening treatments, a general correlation with the presence of defects was observed, but without a clear differentiation between the treatments. The high incidence of embedded particles among the observed defect further strengthens the role played by the particles upon defects generation, some of which later evolve into full cracks. It was also found that the dimensions of the implant (width and length) were not correlated with the observed defects, for this specific sample.

Our observations indicate that early retrieval of biologically failed implants, many of which contain early signs of mechanical failure as shown here, does actually hinder the later occurrence of implant fracture. It seems that once biological complications will be successfully overcome, such defects might grow later into full cracks as a result of cyclic mastication loads (fatigue). In such a case, the occurrence of implants' fracture is likely to markedly increase.



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http://dx.doi.org/10.1016/j.jmbbm.2015.05.014
1751-6161/

## 1. Introduction

Treating partially dentate patients with dental implants is generally considered today as a safe and predictable treatment, with a ten-year survival rate of over 93% (Pjetursson et al., 2010). That means that after a follow up time of 10 years, 93% of the implants are still in the jaw bone and 7% had to be removed and are considered lost.

During service, implants, just like any other mechanical structure, may experience complications. Those complications can be of a biological or a mechanical nature. Complications, as severe as they can be, do not necessarily lead to the loss or extraction of the implant and more often they can be treated and/or controlled.

Unfortunately, some can lead to the implant loss. Implant loss can be divided into two categories. The first, early losses, which occur no later than 6 months after implantation, or before the implants are loaded. The second, late losses, occurs beyond a period of 6 month after implantation (Pjetursson et al., 2010; Tonetti and Schmid 2000; Berglundh et al., 2002; Goodacre et al., 2003).

Early losses are mainly of a *biological* nature, during which the process of osseointegration could not be achieved due to surgical trauma, infection during the implant placement and the healing process, and instability of the implant due to premature loading. More than 50% of implant losses are defined as early losses (Berglundh et al., 2002; Goodacre et al., 2003; Manor et al., 2009).

Late losses can be divided into two groups, according to the cause of loss. Biological causes are related to progressive loss of bone support around the implant because of infection or inflammation, termed peri-implantitis (Pjetursson et al., 2010; Tonetti and Schmid 2000; Berglundh et al., 2002; Goodacre et al., 2003). Approximately 50% of implant losses are defined as late losses, which occur due to loss of bone support (Berglundh et al., 2002; Goodacre et al., 2003; Manor et al., 2009). Most of these losses occur during the first year after loading (Goodacre et al., 2003).

Snauwaert et al., (2000) studied implant lose rate, with emphasis on occurrence over time, of 5000 implants after a follow up time of 15 years. 60% of late biological losses occurred 1 year after loading, and 40% occurred from the second year on.

The second cause for implant loss is related to *mechanical complications*. Mechanical complications are a generic term for mechanical damage of the implant, its components, or to the suprastructure supported by the implant. Implant loss, in the context of mechanical complications, includes of course implant fracture, which is considered a severe complication requiring extraction of the implant and its supporting bone (Snauwaert et al., 2000; Simonis et al., 2010; Gealh et al., 2011; Papaspyridakos et al., 2012).

A series of recent systematic reviews, based on several clinical studies with at least 5 and 10 year follow up periods, reported a high incidence of such mechanical complications' (Pjetursson et al., 2010, 2014; Papaspyridakos et al., 2012) with a 5-year complication rate for a total number of mechanical complications ranging from 16.3% to 53.4%. Pjetursson et al. (2014) Fracture of the fixation screw is one of the most common mechanical complication, with a 5 and 10 year estimated complication rate of 9.3% and 18.5%, respectively. Implant fracture is considered a severe but rare complication, with a 5 year complication rate of up to 4% (Pjetursson et al., 2014). Dhima et al. (2014) presented a long-term retrospective study evaluating the outcome of 1325 implant, after a follow up time of 29 years. Mechanical complications were more frequent than biological ones. Well over half (58%) of the implants experienced at least one mechanical complication. The study also showed that mechanical complications occur significantly later than biological complications, with a mean time of 5 years for biological complications to occur versus 7.6 years for mechanical complications. Fracture of the fixation screw (8.5%), and abutment fracture (5.5%) were the top observed mechanical complications.

Regarding implant fracture, 6% of the lost implants are the result of implant fracture, according to Manor et al. (2009). In parallel, Pommer et al. (2014) recently published a systematic review meta-analysis on the incidence of implants' fracture, reviewing a large number of clinical studies that reported such fractures. Their study estimated an incidence of implant fracture to be 2.8% after a follow up time of 8 years. Most fractured implant included in this study occurred just after a mean time of $4.1 \pm 3.5$ years. These incidences clearly highlight the *importance of the follow up time* on the occurrence of implant fracture.

All these studies, dealing with implant loss and implants complication rates, have clearly pointed out that mechanical complications, and among them *implant fracture*, do actually occur with a high incidence rate after long follow-up time periods. Mechanical complications occur significantly later and more frequently than biological complications, and their severity is much more pronounced because of the complexity of treatment that ensues.

The identification of the probable causes leading to mechanical complications is important in order to prevent their recurrence. Mechanical complications can be related to several parameters. The type of restoration supported by the implants, when the type of restoration whether removable or fixed prosthesis, may influence the loads that are transmitted to the implant and thus the incidence of mechanical complications (Berglundh et al., 2002). Occlusal loads' magnitude is a key factor contributing to the load imposed on the implants. Parafunction habits such as bruxism and clenching may increase the load magnitude on the implant/ prosthesis system leading to early occurrence of mechanical complications (De Boever et al., 2006) Aside from the above clinical reasons, mechanical reliability of implants depends also on their overall design, materials used and surface treatments for improved osseointegration. Examining the fracture surface of retrieved fractured dental implants and implant components (fractographic analysis) is the optimal procedure to assess structural integrity. *Metal fatigue* (Suresh, 1994) has been identified as the implants' main fracture mechanism by many studies (Gealh et al., 2011; Morgan et al., 1993; Shemtov-Yona and Rittel, 2014). The cause(s) for fatigue crack initiation was first shown to be related to *implant design* that includes significant stress concentrators (Morgan et al., 1993; Shemtov-Yona et al., 2014b, 2014c). Accelerated fatigue failure was also observed for implants that were cyclically loaded in a saliva-like environment, (Shemtov-Yona et al., 2014d) indicating the potentially adverse effects of the in-vitro atmosphere. Moreover, the surface roughening procedure,