Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 62 (2017) 429 – 434

www.elsevier.com/locate/procedia

10th CIRP Conference on Intelligent Computation in Manufacturing Engineering - CIRP ICME '16

Dental failure analysis: the need of a comprehensive failure classification

Andrea Gatto[a], Luca Iuliano[b], Eleonora Atzeni[b], Paolo Minetola[b], Alessandro Salmi[b,*]

[a]*Università di Modena e Reggio Emilia, Department of Engineering "Enzo Ferrari", Via Pietro Vivarelli, 10, 41125 Modena, Italy*
[b]*Politecnico di Torino, Department of Management and Production Engineering, C.so Duca degli Abruzzi, 24, 10129 Torino, Italy*

* Corresponding author. Tel.: +39-011-090-7210; fax: +39-011-090-7299. *E-mail address:* alessandro.salmi@polito.it

Abstract

For more than thirty percent of patients with implant-supported fixed dental prosthesis, various complications can be observed over five-years of function. In some cases, failure can be ascribed to mechanical reasons such as loosening of the retaining screws or fracture of the implant components. The paper evaluates three different failures of implant-supported prostheses. All cases were analyzed by optical and SEM microscopy to identify the failure modes and the possible failure causes. Improper design or errors in finishing operations or in assembly are identified as dental failure causes. A matrix classification is proposed to collect rupture cases of implant-supported prostheses.

Peer-review under responsibility of the scientific committee of the 10th CIRP Conference on Intelligent Computation in Manufacturing Engineering

Keywords: Implant-supported prosthesis; Failure analysis; SEM; Finishing; Assembly

1. Introduction

At present, implant-supported prostheses are commonly used in dental treatment. Diverse single tooth implants or implant-supported overdentures are available for prosthodontic rehabilitation [1]. In case of implant-supported restorations, the abutment can be retained to the fixture by screw or cement. Connecting bars are used as a common practice in attachment systems supporting removable overdentures. Overdenture bars can be produced by soldering, casting, spark erosion or even precision milling [2].

The duration of the restoration in implant prostheses can be affected by biological or technical complications. The literature evidences that for more than thirty percent of patients with implant-supported dental prosthesis, various complications can be observed over five-years of function [3]. From the technical point of view, screw loosening of implant prosthesis or fracture and cracking of the dental implant components have been reported as the most common restorative complication, especially in single tooth implants in the premolar and molar areas [3-6]. Scientific evidence is lacking to demonstrate the need of precision between implant and prosthetic components for long-term osseointegration, however lack of prosthesis accuracy at the implant-abutment interface has been related by many authors both to screw loosening and screw fracturing [7]. The research evidenced that the lack of fit between components may be due to finishing manufacturing problems and low geometric tolerances. The inherent machining tolerance of all the implant components must be reduced to a minimum, to guarantee close fit between the coupling surfaces, for example of the abutment and the implant, and save mechanical and biological complications [8-10].

Considering overdenture bars, the clamped joint instability (screw loosening and fracture) is one of the common complication encountered [11]. At present, for overdenture bars there is absence of evidence in relation to the specific nature, position, or cause of failure. Some authors [2] stated that there is a need for more reports on both the laboratory-based and clinical factors that could be related to the etiology of soldered or cast bar fractures or failures. Goodacre and colleagues [12] reported that there are essentially six possible causes for metal framework fractures, including overdenture bars. These may be classified and grouped as:

- *design causes*, inadequate metal thickness, excessive cantilever length; alloys with inadequate strength; improper framework design;

Peer-review under responsibility of the scientific committee of the 10th CIRP Conference on Intelligent Computation in Manufacturing Engineering
doi:10.1016/j.procir.2016.06.043

- *manufacturing causes*, poor solder joints;
- *"environment" causes*, parafunctional habits of patients.

A method to determine the cause of the metallic fracture is based on the identification and classification of modes of failure [2]:

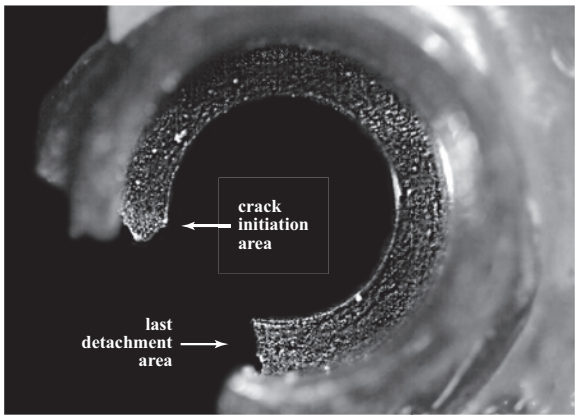
- *progressive failure*, fatigue, corrosion, wear, and creep;
- *instantaneous failure*, ductile overload and brittle overload.

The effects of the manufacturing processes are usually underestimated even if the finishing phase has great influence on the cracks generation and propagation. For example, the absence of concentricity between roughing and finishing tool axis (therefore the mismatch alignment between components axis) amplifies the effects of the complex stress state.

To prevent the failure due to mechanical reasons several approaches may be followed such as simulation and finite method analysis. The finite element method (FEA) is an efficient tool for testing dental implants, but it is still often very difficult to obtain useful and valuable results for the timelife and breakdown prediction of these kinds of device. The main reason for this is the complexity of biostructures and the complexity of numerical simulations stemming from that [4]. Alternatively, engineering methods and electron microscopy (AFM, SEM, TEM) can be used to assess the causes of possible mode of failure or to identify evidence of potential failure in the future of dental implants. Optical microscopy and scanning electron fractography are commonly applied in biomechanics, where they are used to analyze crack initiation and propagation of failed structures that have been subjected to cyclic multiaxial loading. However, the application in dentistry is very limited.

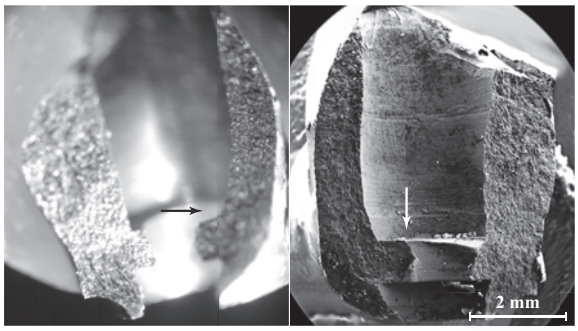
The aim of this study is the analysis of the failure of three different implant-supported prosthesis, an overdenture bar and two single tooth implants, based on the SEM observation of the failed surfaces. The analysis evidences that failures can be ascribed to manufacturing, design and assembling causes.

(a)



(b)

Fig. 1. (a) Overdenture bar and (b) detail of the fractured area.



(a) (b)

Fig. 2. (a) crack initiation observed on the rupture surface of the bar, (b) the arrow indicates last detachment area of the cylinder.

2. Materials and Methods

The analysis developed in this study involved the observation of three different implant-supported prostheses which featured a failure:

- *an overdenture bar manufactured by soldered joints with bilateral distal extension cantilevers*, failure occurred through the cylinder of one of the cantilever extensions;
- *an implant-abutment with internal hex connection*, failure of the hex connection occurred few tens of hours after the implantation;
- *an implant-abutment with screw retention*, failure occurred with screw loosening.

Failure surfaces of each prosthesis were examined under optical microscope and scanning electron microscope to identify the cause of failure. The overdenture bar with failed abutment was previously observed by optical microscope. Thereafter, the polymer was removed from the bar and the rupture surface was ultrasonically cleaned for 10 minutes by placing the bar in a glass beaker containing methanol. Similarly, the implant-abutment with internal hex connection was placed in a glass beaker containing 10% glacial acetic acid solution and ultrasonically cleaned for 10 minutes. On the contrary, the screw was observed as provided without any cleaning treatment.

3. Results

3.1. Overdenture bar failure

The overdenture bar is made of Cobalt-Chrome alloy joint by soldering and with a polymer coating. Figure 1 and 2 show observations by optical microscope of the overdenture bar. A