SEM AND FRACTOGRAPHY ANALYSIS OF SCREW THREAD LOOSENING IN DENTAL IMPLANTS

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Biological and technical failures of implants have already been reported. Mechanical factors are certainly of importance in implant failures, even if their exact nature has not yet been established. The abutment screw fracture or loosening represents a rare, but quite unpleasant failure. The aim of the present research is an analysis and structural examination of screw thread or abutment loosening compared with screw threads or abutment without loosening. The loosening of screw threads was compared to screw thread without loosening of three different implant systems; Branemark (Nobel Biocare, Gothenburg, Sweden), T.B.R. implant systems (Benax, Ancona, Italy) and Restore (Lifecore Biomedical, Chaska, Minnesota, USA). In this study broken screws were excluded. A total of 16 screw thread loosenings were observed (Group I) (4 Branemark, 4 T.B.R and 5 Restore), 10 screw threads without loosening were removed (Group II), and 6 screw threads as received by the manufacturer (unused) (Group III) were used as control (2 Branemark, 2 T.B.R and 2 Restore). The loosened abutment screws were retrieved and analyzed under SEM. Many alterations and deformations were present in concavities and convexities of screw threads in group I. No macroscopic alterations or deformations were observed in groups II and III. A statistical difference of the presence of microcracks were observed between screw threads with an abutment loosening and screw threads without an abutment loosening.

The long term predictability of osseointegrated oral implants is well documented. Currently, implant failures are thought to be due mainly to overload and bacterial infection of the peri-implant tissues. Several studies have reported favourable long term results for different implant systems (1-2) . Implant success rates of several systems are reported to be as high as 95% over 5 years, 90% over 10 years and 75% after 15 years (3). Nevertheless, biological and technical failures of implants have also been reported (4). Mechanical factors are certainly of importance in implant failures, even if their exact nature has not yet been established (5). They often lead to difficult problems including an abutment loosening. The abutment screw fracture or loosening represents a rare, but quite unpleasant failure. Numerous studies have indicated that, after implant osseointegration, abutment screw loosening appears to be the most common problem associated with implants (6). During the first year, fistula formations and inflammation of soft tissues were frequently associated with loose abutment screws; however, during the second and third years of follow-up, fistula formation unrelated to loose abutment screws was also observed (7). Some studies indicate that the majority of failures are associated with the suprastructure rather than with the implants itself (9-10). As screw loosening was encountered as the most common problem, alternative abutment systems, including cementation of the restoration, were developed (11). The objective of the present research was an analysis and structural examination of screw threads with an abutment loosening compared to screw threads without an abutment loosening.

MATERIALS AND METHODS

Patients with a loose suprastructure were selected for this study. Three different implant systems, Branemark (Nobel Biocare, Goteborg, Sweden), T.B.R. implant systems (Benax, Ancona, Italy) and Restore (Lifecore Biomedical, Chaska, Minnesota, USA) were evaluated in this study. Broken screws were excluded. A total of 32 screw threads were observed. Sixteen screw threads with an abutment loosening were observed (Group I) (4 Branemark, 7 T.B.R. Implant systems and 5 Restore), 10 screw threads without abutment loosening were retrieved (Group II), and 6 screw threads as received by the manufacturers (unused) (Group III) were used as controls (2 Branemark, 2 T.B.R. Implant systems and 2 Restore). The screw threads were analyzed under SEM and for fractografy. The analysis performed were a microstructure characterization and fatigue crack initiation at the thread level of the screws of the 3 groups. The hypothesis under test assumed that there were differences between the groups.

Processing of specimens. Screw thread evaluation was performed under SEM after washing [all retrieved specimens were preliminary washed] for 5 min in acetone using an ultrasonic cleaning equipment. The surface of the screw threads was evaluated with a Leo 435 VP scanning electron microscope (LEO, Cambridge, UK). Both samples using were embedded in a glycolmethacrylate resin (Technovit 7200 VLC, Kulzer, Wehrheim, Germany). After polymerization the specimens were sectioned longitudinally along the major axis of the screw with an high-precision diamond disc at about 150 μm and ground down to about 30 μm and thin ground sections with the Precise 1

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Automated System (Assing, Rome, Italy) (10). Three slides were obtained for each screw. The slides were etched by an ethanol solution of 0.5% HF in distilled water at 20°C, and observed under optical microscopy (Laborlux S, Leitz, Wetzlar, Germany).

Morphometry. The number of cracks and threads state of the 3 groups of specimens were examined under a light microscopy (Laborlux S, Leitz, Wetzlar, Germany) connected to a high resolution video camera (3CCD, JVC KY-F55B) and interfaced to a monitor and PC (Intel Pentium III 1200 MMX). This optical system was associated with a digitizing pad (Matrix Vision GmbH) and a mometry software package with image capturing capabilities (Image-Pro Plus 4.5, Media Cybernetics Inc., Immagini & Computer Snc Milano, Italy).

The same samples were sputtered with gold (Emitech K 550 Emitech Ltd. Ashford, Kent,UK) and evaluated under scanning electron microscopy (SEM LEO 435vp Cambridge, UK), in order to evaluate the metal microstructure and the cracks.

Statistical evaluation. The number of cracks in the groups, expressed as a mean +/- standard deviation, were evaluated using the Analysis of Variance (ANOVA), while the significance of the differences observed was inferred with the Bonferroni test for multiple comparisons (Table I). Statistical significance was set at $p< 0.05$.

RESULTS

Group I (screw threads with abutment loosening). Many alterations and deformations in the screws' surfaces were present in the concavities and the convexities of the screw threads (Fig. 1). The thread appeared deformed in the convexities, while, in the concavities, some fatigue cracks were present (Fig. 1). The metal microstructure in the convexities appeared strained with very small cracks present at grain boundaries. In the concavities the fatigue cracks were long and normally oriented in respect to the long axis of the screws (Fig. 1). The fine surface structures of the all the samples were observed, and the depth of the fine structure was found to be about 50–100 μm from the surface. Cracks were detected in the fine grain structures as shown in (Fig. 1). In general, the root of the thread was not in direct contact with the crest of the internal thread. In the fractography of the outer parts of the sample shown, the shear cracks and trace of the crack propagation through the fine grain structures could be detected, and flake structures had formed. The crack growth appeared to be related to the high number of cracks coalescence events.

Group II (screw threads without abutment loosening). No macroscopic alteration or deformation could be observed. The convexities of the threads were deformed and altered (Fig. 2), and the metal microstructure appeared strained but without any cracks (Fig. 6). In the concavities no deformation or fatigue cracks were observed. No microcracks were detected at the root of the screw threads.

Group III (unused screw threads). No macroscopic alterations or deformations were observed. No alterations or deformations in the convexities of the screw thread were present, but rough spots, grooves, and irregularities can be observed (Fig. 3).

Statistical evaluation. Statistically significant differences were found in the number of cracks in group 1 vs group 2 and group 3. ($P= 0.008$)

DISCUSSION

One problem in the restoration of single implants is the loosening or fracture of the abutment and retaining screws. Complications such as chronic screw loosening and fracture, in addition to prosthesis and implant fractures, have been reported (12). Prosthetic complications can be very costly and time-consuming, therefore, there has been a concerted effort by clinicians and manufacturers to try to reduce the occurrence of these problems (13). Different reasons may explain the loosening. One is the rotational misfit between two parts. This is due to the difficulties with such small dimensions (14). First, the implant should be placed in a location so that the occlusal forces are directed along the long axis of the implant. Second, cantilevers should be kept to a minimum. Third, occlusal contacts are important, and establishing them in cusp-to-fossa relationships instead of cusp tip to cusp tip is preferable. Preload is introduced in a screw when torque is applied during tightening. Preload is that which keeps the screw threads tightly secured to the mating counterpart of the screw and holds the parts together by producing a clamping force between the screw head and its seat (15). Adequate torque placed on the gold abutment screw is necessary for the maintenance of preload. Most studies evaluate the amount of torque placed on implant screws (16). The amount of torque placed on the dental implant screw is operator dependent (17). The amount of preload present at the threads of a prosthetic retaining screw depends on the applied torque (18), the presence and type of lubricant, the physical properties of the materials in contact, and the settling of the screw after initial torquing (19). Surface imperfections lead to increased friction and decreased preload. Removal and retorquing of the screw reduce surface imperfections, and the use of lubricants decreases friction, both result in increased preload (20). For this reason the use of cements and seal by silicon in addition to torque controllers can be very risky and can cause the fracture of the screw (21). Elevated torque can cause and facilitate loose screws or fracture the retained screw (21). Mastication induces a combination of vertical and horizontal forces due to the complex motion of the mandible and the inclination of tooth cusps. Other mechanism that facilitates the screw's looseming is a microgap between body of implant and screw. These microgaps have been found in all implants. In clinical practice it seems that it is very difficult to reduce the dimension of this microgap. The presence of voids certainly facilitates the screw's loosenings and bacterial

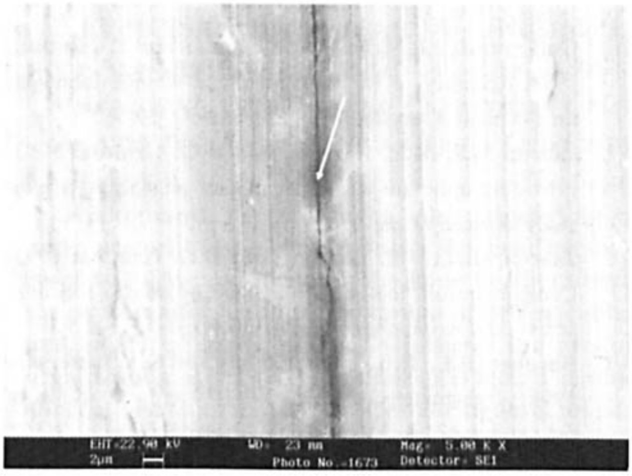

Fig. 1. *SEM image at 5.000 X of a screw. Many particles and some damaged areas are present on the screw surface. In the concavities the fatigue cracks were long and normally oriented respect to the long axis of the screws.*

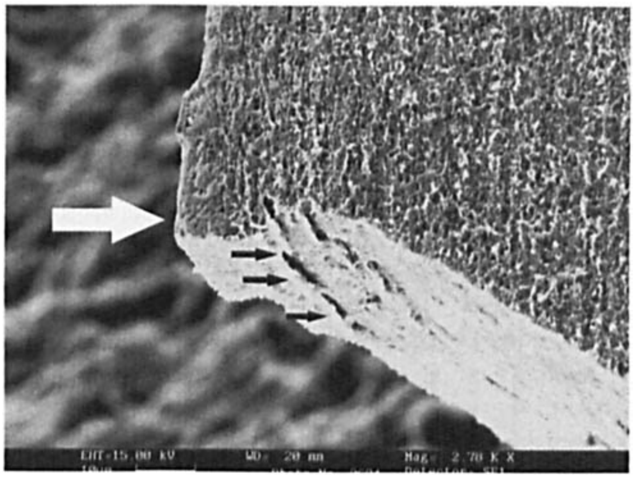

Fig. 2. *SEM micrograph at 2780 X of a screw sectioned longitudinally. The top radius of the thread appears deformed (arrow) and some fatigue microcracks are present (black arrows).*

migration (22) as well as the presence of bacteria inside the implants and corrosion of implant components (23). In conclusion, a statistical difference was observed between screw threads with abutment loosening and screw threads without abutment loosening. For this reason a rescrewing of a loosened abutment should not be done because it can increase the risk of a fracture of the abutment.

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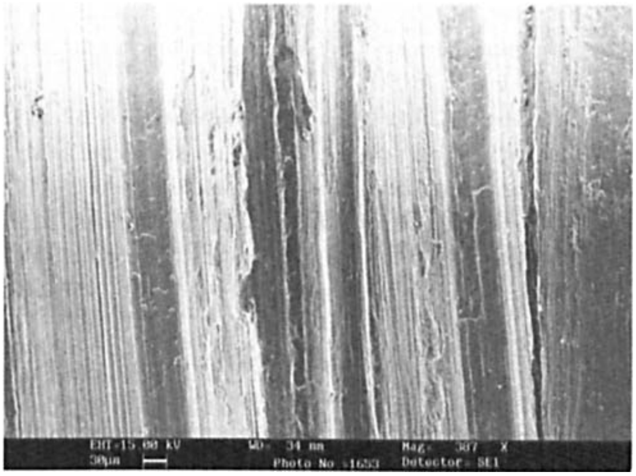

Fig. 3. *SEM image at 387 X of distal threaded portion of new screw shows rough spots, grooves, and irregularities.*

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