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ORIGINAL RESEARCH

Biomechanical Aspects in Late Implant Failures: Scanning Electron Microscopy Analysis of Four Clinical Cases

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ABSTRACT

Aim: The aim of this work is to analyze by scanning electron microscopy implant components that have mechanically failed *in vivo*.

Materials and methods: Three clinical cases are presented relative to single lateral posterior restorations supported by implants and a case of a mandibular overdenture supported by two implants. In all the reported cases the presence of an incongruous occlusal load caused the fracture of the components of the implant supported restorations.

Conclusion: From the analysis of the cases examined in this study, it is deduced that the functional overload influences the biomechanical behavior of the prosthetic rehabilitation supported by an implant and may, in less fortunate cases, determine the failure following the fracture of the connecting screws and/or the fixture.

Keywords: Implants, Prosthesis, Biomechanical failure.

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INTRODUCTION

The use of an implant supported restoration in the treatment of a single missing tooth is a solution that is widely used in clinical practice today. On the other hand, the literature reports on the complications that can arise in a restoration supported by an implant; Tonetti and Schmid[1] classify the failures as 'early and late': the first are relative to the loss of the fixture before it is loaded and often originate in problems connected with the surgical protocol.

The tardy failures, instead, happen after the fixture has been prosthesized and are often due to more than one factor; they are often clinically difficult to deal with; mechanical complications, in fact, may arise from the failure of the prosthetic therapy following the fracture of the connecting screws or of the fixture. Adell et al[2] report an incidence of fracture of the fixture of 5%, while Schwarz[3] report an incidence of 12.5% in implants inserted into the maxilla and 14.3% in implants inserted into the mandible. Relative to the connecting screws, Ekfeldt et al[4] report that the loosening of these is the most common complication and other authors agree that the loosening of the abutment is a problem that compromises the long-term success of prosthetic rehabilitation;[5-7] Jemt (1991)[8] also states that the loosening of the connecting screws occurs more frequently in single implant supported restorations rather than in bridges. In screwed connection implant systems, the mechanical continuity between the abutment and the fixture is fundamentally secured by the preload applied to the screws during the tightening, according to the degree of adaptation, that is precision, existing between the abutment and the fixture (Figs 1 and 2). McGlumphy et al[9] also report that the preload depends on the following factors: (a) the applied torque, which has direct influence on the underhead friction, on the friction of the coils and on the degree of elastic/plastic deformation that the system undergoes; (b) the geometry of the head of the screw, that influences the degree of underhead friction; (c) lastly, the material used for the screws and the abutment determine the level of grip between the two structures. Regarding the biomechanics, therefore, the application of a certain degree of torque by the operator is expressed in the form of a preload, that is a force able to obtain the mechanical continuity between the structures; such force is found in the friction between the surfaces and in the elastic as well as plastic, deformations that arise in the structure. On a clinical level, during the functioning the prosthesis is submitted to cyclic forces that may result in the separation of the abutment from the fixture;

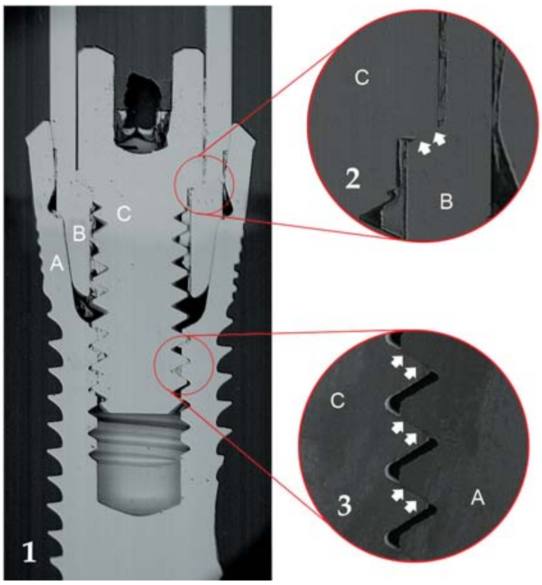

Fig. 1: (1) SEM imaging of the fixture-abutment-screw complex in longitudinal section; A: fixture; B: abutment; C: fixing screw. The mechanical contiguity between the parts is given by the preloading (torque) applied to the screw during the tightening; from a biomechanical point of view, the torque applied provides retention to the system because it produces a superficial plastic deformation on the opposing surfaces. In screw connected implant systems only two areas exist in which the retentive function is expressed, represented by the screw underhead (2) and by the screw spirals in contact with the internal thread of the fixture (3). In fact, in images (2) e (3) the arrows indicate the close contact obtained following the tightening of the connecting screw

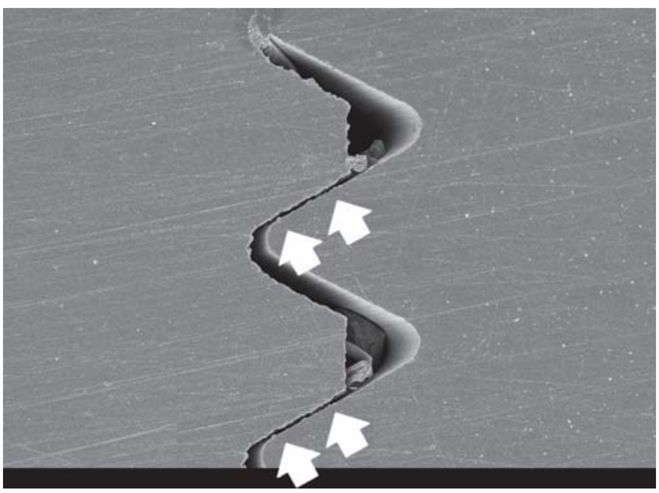

Fig. 2: SEM imaging (longitudinal section) of a fixture-screw connection complex subjected to a nonaxial overloading. The detrimental effects of the overload are expressed morphologically, with the loss of contact between the connecting screw and the internal thread of the fixture, which means the loss of the preload; clinically, this condition determines the appearance of mobility of the prosthetic unit in respect to the fixture and, in the most severe cases, can result in the fracture of the connecting screw

the undesired loosening of the screws is, in fact, normally caused by the transversal load dynamics, transversal displacements, elastic deformation due to knocks, vibrations or sudden changes in temperature, all situations that determine various dilations/contractions of the components of the prosthesis.

The aim of this work is to carry out a scanning electron microscopy analysis on implant components that have mechanically failed *in vivo*.

CLINICAL CASES

Case 1

In this case, restoration is performed in a 47-year-old male patient. Single crown element 3.6. The fixing screw loosened after about eight months; the patient came for a checkup after about two months from the start of the mobility of the prosthetic element. The SEM analysis of the fixing screws showed a fracture line between the first and second turn, probably originating during the eight weeks of use with the partially mobile element (Figs 3 and 4).

Fig. 3: SEM imaging (71×) of a connecting screw; a fracture line can be seen between the first and second spirals of the screw thread

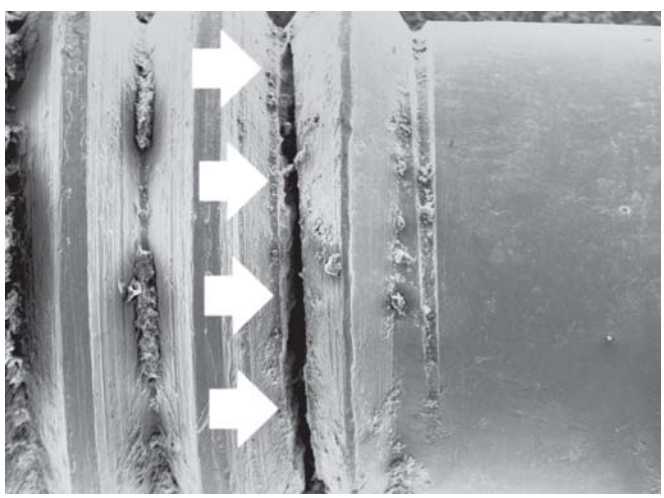

Fig. 4: Detail of Figure 3 (165×)

Case 2

In this case, restoration is performed in a 51-year-old male patient. Single crown element 3.6. The prosthesis fractured in correspondence to the neck of the fixture after 13 months use. The presence of an incongruous occlusal load, in association with a mechanical failure determined the fracture of the connecting screw due to strain (Figs 5 and 6).

Case 3

In this case, restoration is performed in a 39-year-old female patient. Single crown element 4.5. The cyclic load applied during the period of loosening of the crown determined the fracture due to strain of the connecting screws (Figs 7 to 9).

Case 4

In this case, restoration is performed in a 64-year-old male patient. Inferior overdenture. The functional loading, applied on a line which did not coincide with the axis of the implant, produced an unfavorable biomechanical condition. Furthermore, the loss of integration dependent on the most coronal part of the implant moved the fulcrum in an apical direction, determining an increase of the lever arm; this

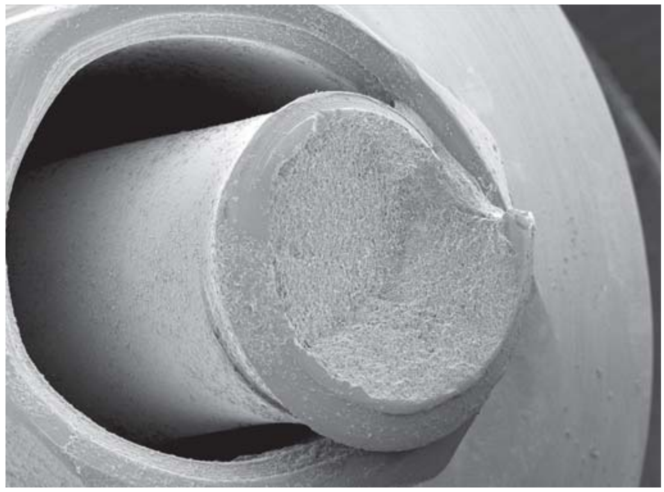

Fig. 7: SEM imaging (105×) of an abutment with a fractured screw

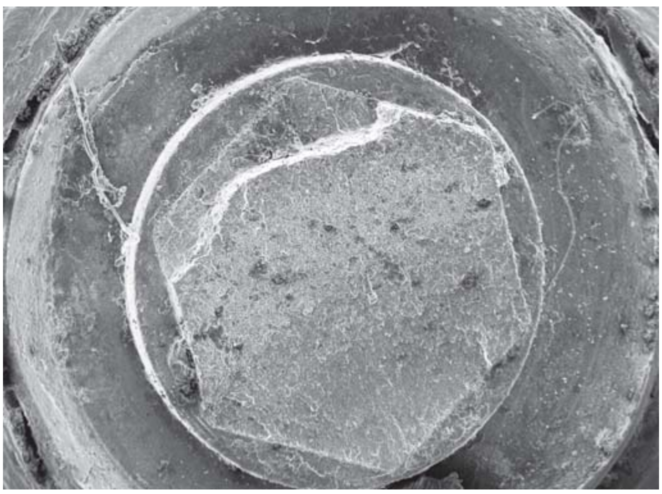

Fig. 5: SEM imaging (45×) of a crown prosthesis fractured at the fixture connection

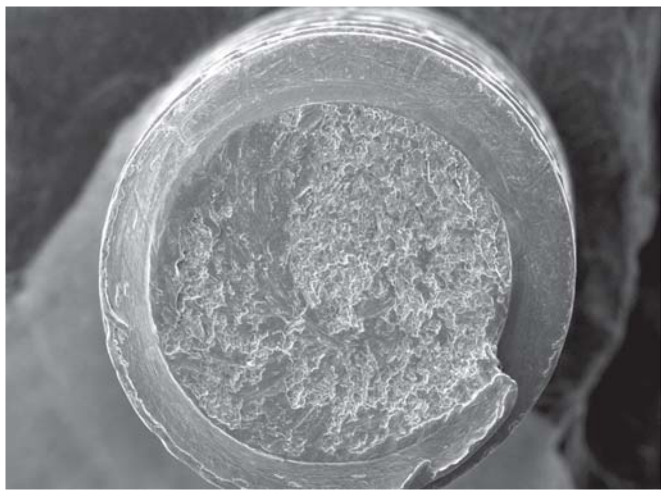

Fig. 8: SEM imaging (110×) of a fractured screw

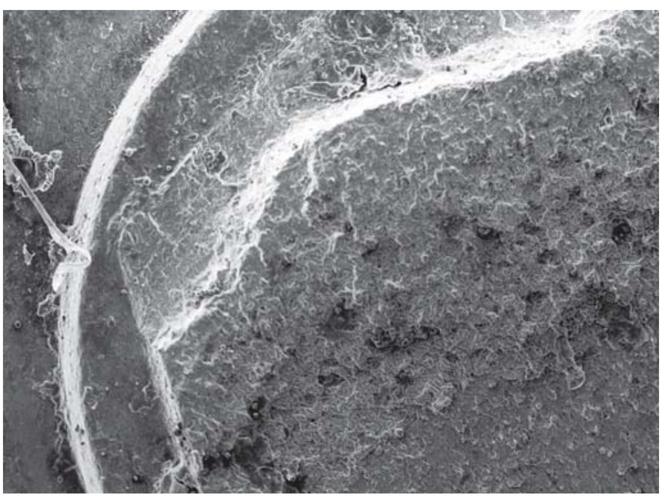

Fig. 6: Detail of the fractured area (165×)

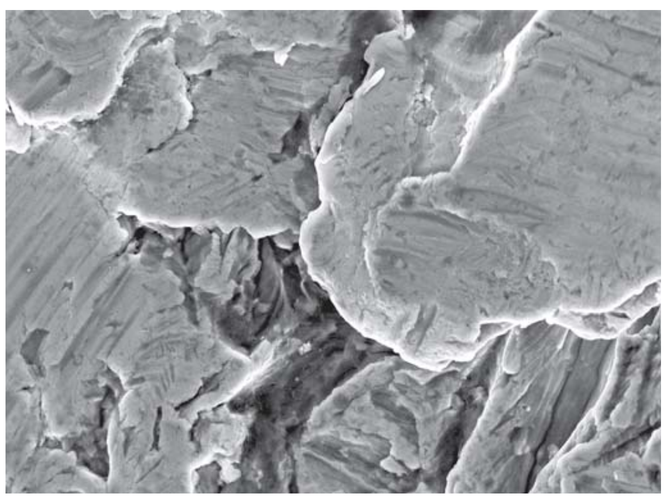

Fig. 9: Detail of Figure 8 (6720×)

resulted in an alteration of the mechanical balance which caused the fixture to fracture (Figs 10 and 11).

DISCUSSION AND CONCLUSION

During chewing movements the cutting and vertical forces are discharged on the clamping screws, generating a twisting moment: when the intensity of these forces exceeds the preloaded level applied, the screws of the system loosen. Therefore, a condition of mobility of the restoration is set in respect to the fixture in which the functional load applied to the restoration can lead to plastic deformation on the opposing surfaces of the post/fixture interface, i.e. on the fixing screw, or can ultimately lead to the fracture of the screw. In fact, loosening of the fixing screw leads to an increase in incidence of fractures which total about 1.2% of prosthetic complications according to Naert et al[10] whilst Zarb and Schmitt[11] report a 21% incidence of fractures of the fixing screw.

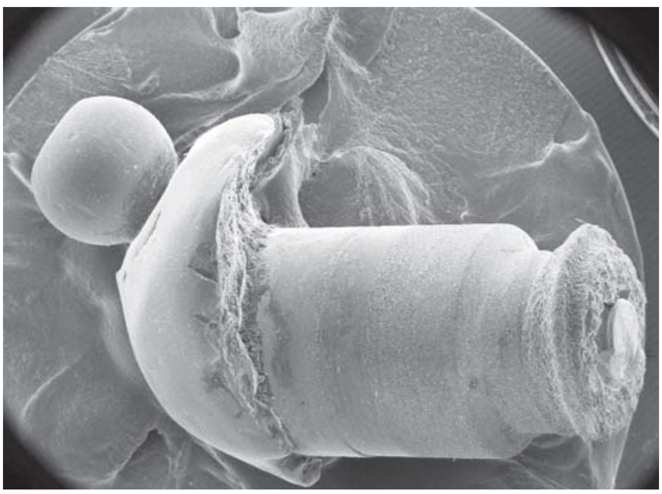

Fig. 10: SEM imaging (28×) of a fixture fractured near the first spiral of the screw thread

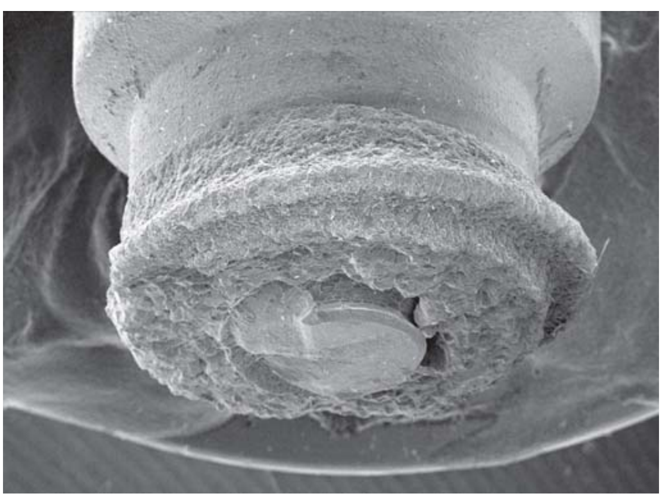

Fig. 11: Detail of Fig. 10 (68×) showing the connecting screw which fractured at the same time as the fixture

It is therefore evident that the increase of the preloading applied during the fixing of the screws, that is the reduction of the dynamic transversal loading, can contribute to the stability and the duration of the fixture/abutment joints of the screwing systems. The limit of the applied load is represented by the mechanical resistance of the prosthetic components, and normally the maximum quantity of torque applied does not exceed 30 Ncm. Regarding the occlusal forces, McGlumphy et al[9] suggest avoiding or reducing the distal cantilevers: to render the occlusal loading parallel to the axis of the fixture-abutment-crown unit; to eliminate both the working and the balancing posterior precontacts; to “centralize” the centric occlusion contacts. In fact, the forces in a tangential direction compared to the axis of the prosthesis generate a moment, the arm of which is represented by the distance existing between the point of application of the loading and the abutment fixing screw.

Regarding single tooth restorations, the presence of a balancing contact produces a lever arm which is unfavorable to the biomechanical economy of the system; this condition becomes even more unfavorable when the axis of the prosthesis is inclined. Lastly, Hoyer et al[12] relate the forces applied during the use of the fixing screw with diverse biomechanical factors, such as the horizontal and vertical components of the occlusal loading, the distance between the loading point of application and the fulcrum and the diameter of the abutment.

By analyzing the cases reported in this manuscript, it can be deduced that the functional overloading influences the biomechanical behavior of the prosthetic rehabilitation supported by the implant and can, in the least favorable cases, determine its failure due to a fracture of the connecting screw and/or of the fixture.

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