A 16-YEAR STUDY OF THE MICROGAP BETWEEN 272 HUMAN TITANIUM IMPLANTS AND THEIR ABUTMENTS

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KEY WORDS

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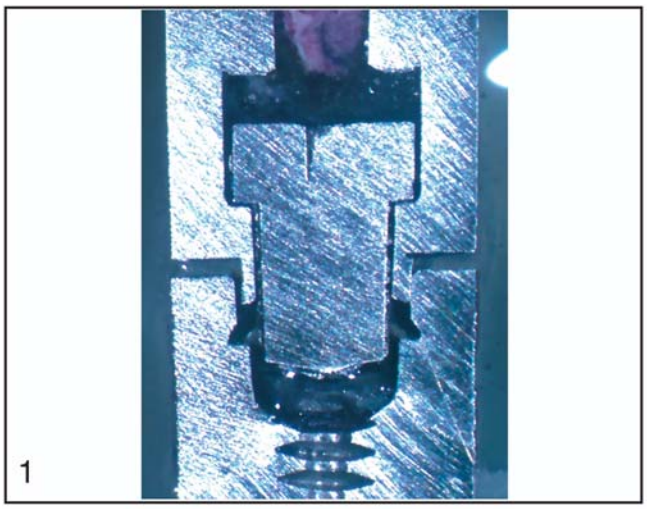
A microgap has been described at the level of the implant-abutment connection. This microgap can be colonized by bacteria, and this fact could have relevance on the remodeling of the peri-implant crestal bone and on the long-term health of the peri-implant tissues. The authors report on 272 implants with screw- or cement-retained abutments retrieved from humans for different causes during a 16-year period. In the implants with screw-retained abutments, a 60-μm microgap was present at the level of implant-abutment connection. In some areas the titanium had sheared off from the surface and from the internal threads. The contact between the threads of the implant and those of the abutment was limited to a few areas. Bacteria were often present in the microgaps between implant and abutment and in the internal portion of the implants. In implants with cement-retained abutments, a 40-μm microgap was found at the level of the implant-abutment connection. No mechanical damage was observed at the level of the implant or of the abutment. All the internal voids were always completely filled by the cement. No bacteria were observed in the internal portion of the implants or at the level of the microgap. The differences in the size of the microgap between the two groups were statistically significant ($P < .05$). In conclusion, in screw-retained abutments the microgap can be a critical factor for colonization of bacteria, whereas in cement-retained abutments all the internal spaces were filled by cement. In these retrieved implants, the size of the microgap was markedly variable and much larger than that observed in vitro.

INTRODUCTION

Many implant systems with screw-retained abutments have been in use for several decades with well-documented clinical success.[1] These systems consist of an implant and an abutment joined together with a titanium abutment screw.

The long-term predictability of osseointegrated oral implants has been well documented, and implant failures are fortunately rare.[2,3] It is important to try to understand the etiopathogenesis of these failures in order to minimize them.[2] Moreover, from this knowledge we can hope to improve the quality of the materials and the surgical and prosthetic techniques.[4] Implant failures may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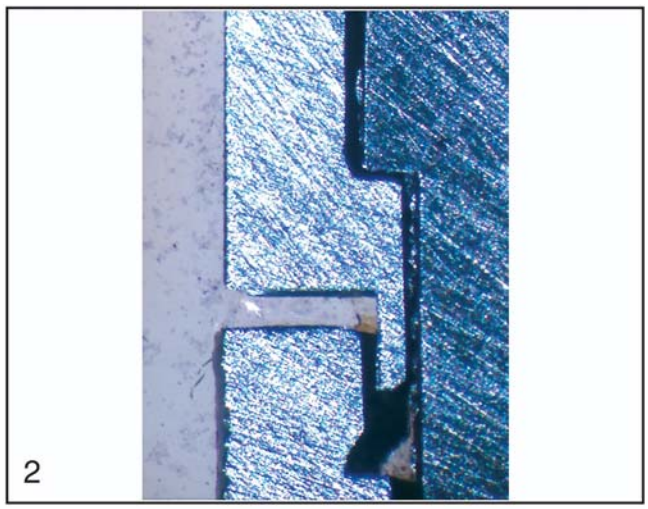
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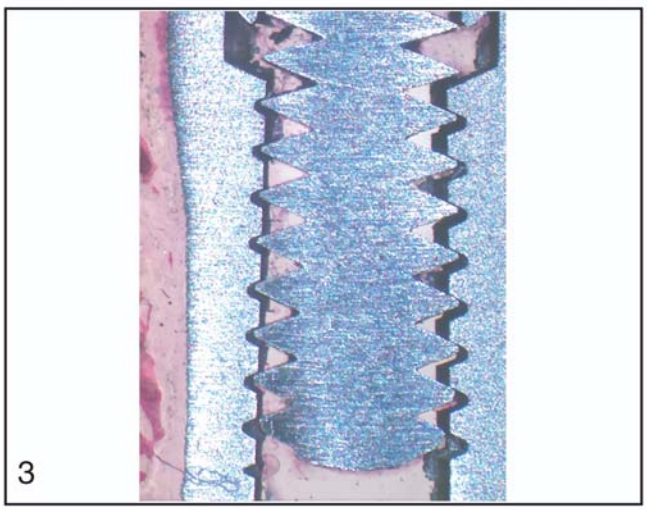
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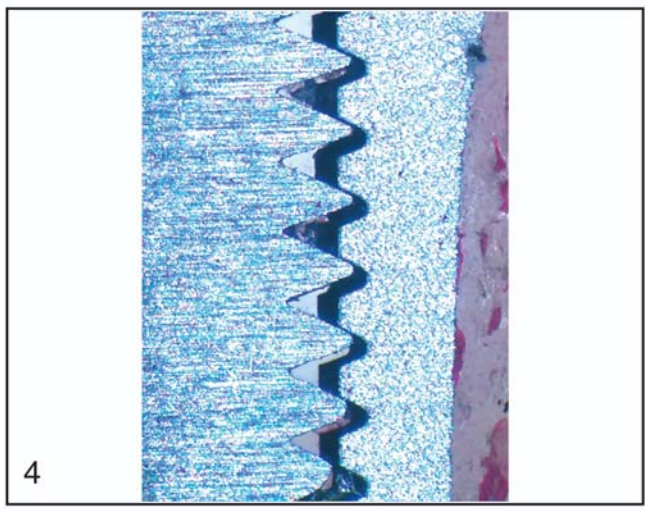
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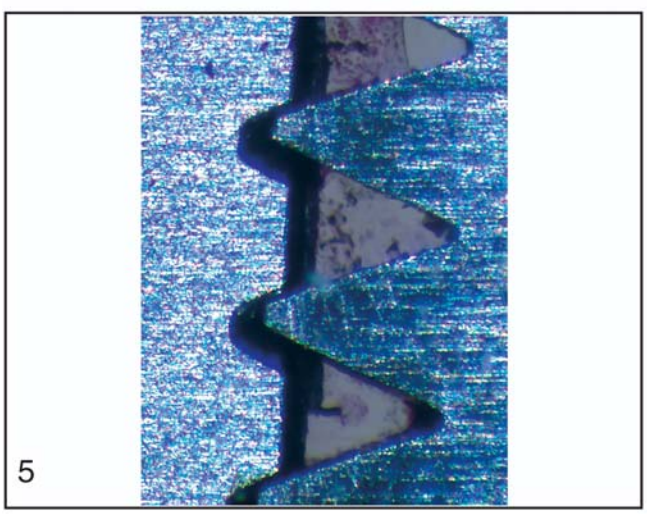
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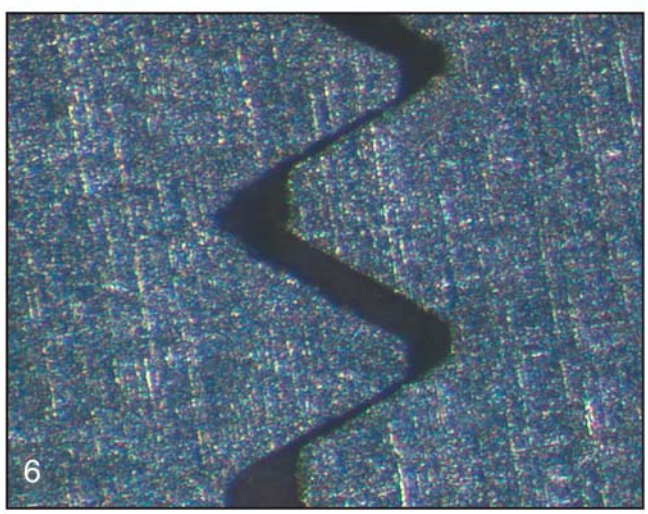
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be categorized as biological, mechanical, iatrogenic, and functional.[4] They most likely originate either from implant overloading or from bacterial infection of the peri-implant tissues.[5–10]

In implants with screw-retained abutments, bacteria can penetrate in vivo and in vitro inside the internal hollow portion of the implant because of a gap at the implant-abutment connection.[11–13] Also, the loosening of the abutment is quite frequent,[14] which can be a problem in implant dentistry.[15] Loosened abutment screws and prosthesis screws are often found at yearly clinical examinations. Loosened screws may cause costly complications, such as screw fractures and fracture of the framework, and methods to prevent them would be very welcome in clinical practice.[16]

The problem of a microgap between implant and abutment is biological and mechanical. The biological problem relates to the presence of bacteria that have been found in the apical portion of the abutment screw[11,17]; in vivo, this could produce a bacterial reservoir that could interfere with the long-term health of the peri-implant tissues. The mechanical problem relates to micromovements and possible loosening or fracturing of screw-retained abutments.[18]

The aim of the present study was an histological analysis of 272 retrieved implants evaluated during a 16-year period (1989–2004). The implants were categorized into 2 groups: 83 implants with cement-retained abutments and 189 implants with screw-retained abutments. In this retrospective study, we evaluated the presence of a microgap between abutments and implants in screw- and cement-retained abutment connections in implants removed for failure.

Methods

We retrieved from our files (years 1989–2004) 272 titanium implants that had been removed for periimplantitis before loading, periimplantitis after loading, mobility, psychological causes, and pathology of the alveolar nerve and that had been sent to our department. In this study all the implants retrieved for mechanical complications were excluded, and all implants had been loaded. The mean time of retrieval after implant loading was 49 months. Only the implants with prefabricated abutments were selected; the implants with custom abutments were excluded. Eighty-one abutments had been cemented with a zinc phosphate cement, whereas in 21 abutments the type of cement used was unknown.

All the implants had been removed with a 5-mm trephine or by gently unscrewing them with stainless steel forceps. The implants retrieved were categorized into 2 groups:

- 170 implants with screw-retained abutments: Branemark implants (Nobel Biocare, Goteborg, Sweden), Implant Innovations implants (Palm Beach Gardens, Fla), and Restore implants (Lifecore Biomedical, Chaska, Minn); and
- 102 implants with cement-retained abutments: Bone System implants (Bone System, Milano, Italy) and Primary Healing Implant system (PHI, San Vittore Olona, Milano, Italy).

Specimen processing

Implants and surrounding tissues were washed in saline solution and immediately fixed in 4% paraformaldehyde and 0.1% glutaraldehyde in 0.15 M cacodylate buffer at 4°C and pH 7.4 to be processed for histology. The specimens were processed to obtain thin ground sections with the Precise 1 Automated System (Assing, Rome, Italy).[19] The specimens were dehydrated in an ascending series of alcohol rinses and embedded in a glycolmethacrylate resin (Technovit 7200 VLC, Kulzer, Wehrheim, Germany). After polymerization, each specimen was sectioned along its longitudinal axis with a high-precision diamond disc at about 150 μm and ground down to about 30 μm with a specially designed grinding machine. A

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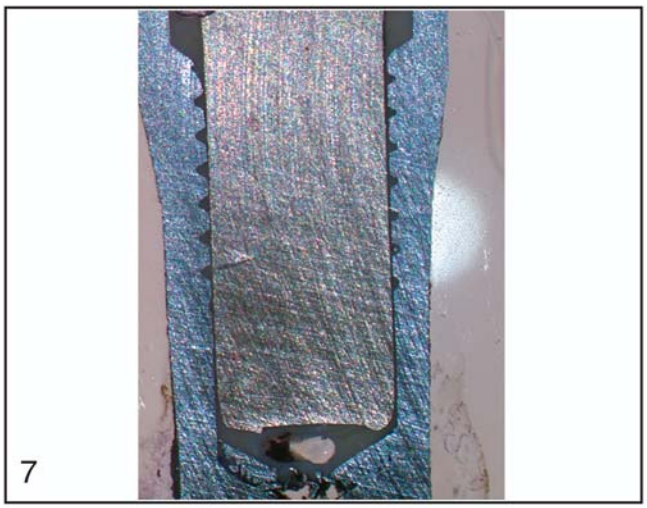
Figures 1–6. Figure 1. A large microgap is present at the level of the implant shoulder (reflected light microscopy, original magnification ×12). Figure 2. Higher magnification of the previous slide. Spaces are present between abutment and implant and between implant and screw (reflected light microscopy, original magnification ×50). Figure 3. Low-magnification examination of a screw-retained implant retrieved after a loading period of 2 years. A scarce longitudinal adaptation between implant and abutment is present (reflected light microscopy, original magnification ×12). Figure 4. Higher magnification of the previous slide. Signs of damage are present at the implant-abutment interface (reflected light microscopy, original magnification ×20). Figure 5. Screw-retained abutment. Voids are present between implant and abutment. Biological fluids are present in these spaces. The contact between implant and abutment is limited to a few points (reflected light microscopy, original magnification ×100). Figure 6. Screw-retained abutment. Few contact points between implant and abutment are present (reflected light microscopy, original magnification ×50). Figure 7. Cement-retained abutment. The cement fills the spaces between implant and abutment (reflected light microscopy, original magnification ×12).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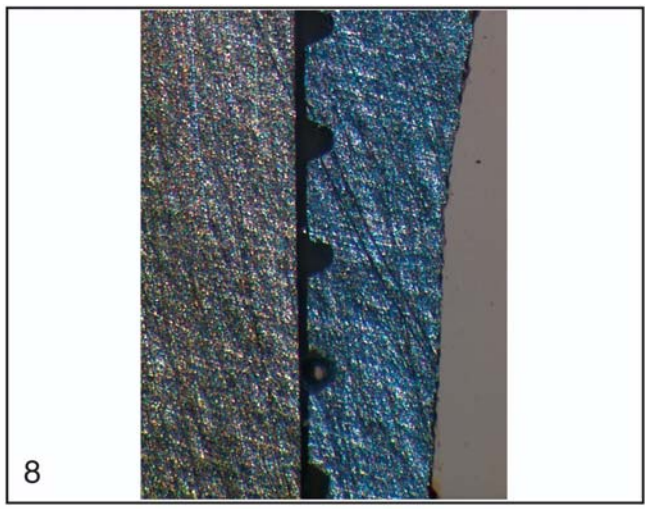
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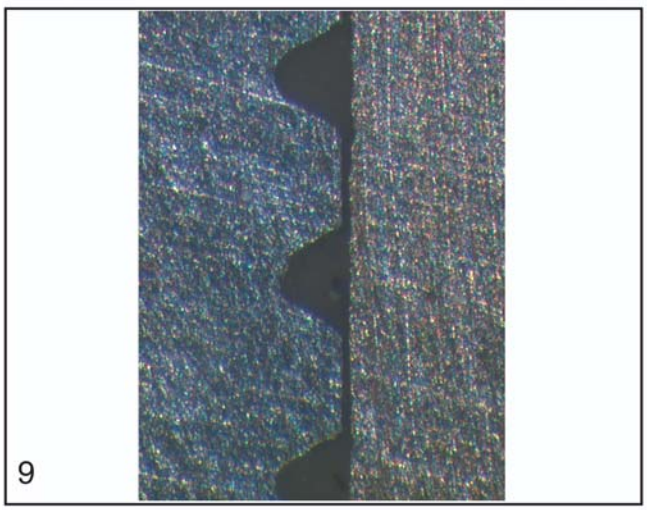
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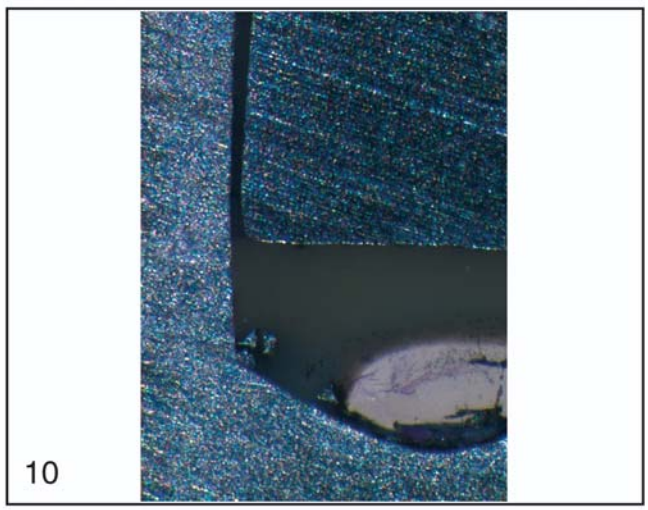
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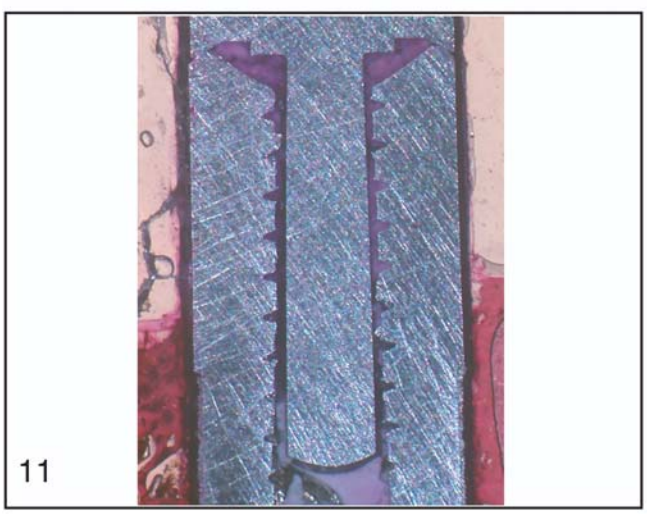
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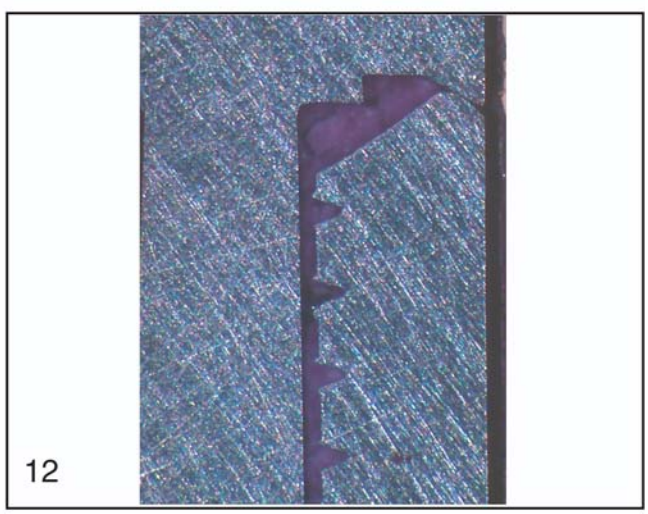
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total of 3 slides were obtained for each implant. The slides were stained with acid fuchsin and toluidine blue and were observed in normal reflecting light under a Laborlux-S light microscope (Leitz, Wetzlar, Germany). Histomorphometry of microgap between abutment and implant was performed with a light microscope (Laborlux S, Leitz) connected to a high-resolution video camera (3CCD, JVC KY-F55B, JVC Professional Products, Milan, Italy) and interfaced to a monitor and personal computer (Intel Pentium III 1200 MMX, Intel Ireland Ltd, Kildare, Ireland). This optical system was associated with a digitizing pad (Matrix Vision GmbH, Oppenweiler, Germany) and a histomorphometry software package with image-capturing capabilities (Image-Pro Plus 4.5, Media Cybernetics Inc, Immagini and Computer Snc, Milan, Italy).

Statistical evaluation

The differences of microgap between implant and abutment in the 2 groups were evaluated with a Student *t* test. The mean of microgap has been expressed as a mean ± SD and SE. Statistically significant differences were set at $P < .05$.

Results

Group 1 (implants with screw-retained abutments)

Numerous gaps (mean 61.3 ± 4.5 μm) were present in the screw-abutment interface (Figures 1 and 2), and in several areas the titanium had sheared off from the surface and from the internal threads. The metallurgical examination showed intra- and infra-angular fractures of the metal in the area of the implant threads and the cover screw. Spaces (50 ± 5.2 μm) were observed between the internal portion of the implant and the threads of the screw (Figure 3). Spaces and damaged areas of the threads were present in all cases. In no case was a perfect adaptation between implant and screw-retained abutment observed (Figures 3 through 6). It was possible to observe the presence of many colonies of bacteria in the gaps between implants and abutments. Bacteria were also present in the internal portion of the implants.

Group 2 (implants with cement-retained abutments)

Cement filled all the spaces, and no damaged parts of the components were present (Figures 7 and 8). In a few cases, an excess of cement was present at the level of the abutment-implant connection, which had a mean gap of 40.4 ± 3.4 μm. The leading edge of the abutment screw thread (superior surface) was in contact with the implant body thread, and most of the contacting surfaces were located in the middle portion of the mating threads. In the space between abutments and implants, it was possible to observe a complete absence of bacteria and of organic material (Figures 9 and 10). In some areas the cement in the microgaps between abutments and implants was fractured. Spaces (20 ± 4.3 μm) were observed at the level of the inner implant and the abutment connection. Biological fluids stained with toluidine blue and acid fuchsin were present in the areas of fractured cement. No cement fracture was present in other zones (Figures 11 and 12). No presence of multinucleated or inflammatory cells near the cement was observed.

Statistical evaluation

Statistically significant differences were found in the dimension of the microgap of the 2 groups ($P \leq .05$).

Discussion

The microgaps between implants and abutments are important for their biological and mechanical aspects. The biological importance of the microgap is related to the crestal bone remodeling, whereas the mechanical importance is related to the possibility of screw loosening and abutment fracture. Some authors have thoroughly studied the significance of the existence and location of a microgap between implant components. In 2-part implants, the bone crest level changes appeared dependent on the location of the microgap, with a distance between the microgap and the most coronal bone-implant contact being approximately 2.0 mm.[21–26] The precise mechanisms

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Figures 7–12. Figure 8. Cement-retained abutment. No gaps are present between implant and abutment. The cement fills all the spaces (reflected light microscopy, original magnification ×20). Figure 9. Cement-retained abutment. No spaces are present between implant and abutment. No organic material is present inside the cement (reflected light microscopy, original magnification ×12). Figure 10. Cement-retained abutment. No gaps are present at the apex of the abutment. The cement fills all the spaces. No organic material or bacteria are present (reflected light microscopy, original magnification ×50). Figure 11. Cement-retained abutment. No gaps are present between implant and abutment. The cement fills all the spaces. No cement fractures are present (reflected light microscopy, original magnification ×12). Figure 12. Cement-retained abutment. No biological fluids are present in the cement. The cement fills all the spaces. No cement fractures are present (reflected light microscopy, original magnification ×50).

of bone loss around dental implants are poorly understood.[27,28] Osteoblasts and osteoclasts are involved in adaptive modeling and remodeling; these cells are able to sense their mechanical environment and regulating deposition or resorption of bone matrix. The osteoclast is the most important bone-resorbing cell, and it derives from the monocyte-macrophage lineage.[29–31] Modeling changes the amount of bone and determines its geometrical form in relation to the prevailing mechanical loads and their resulting deformations (strains).[32,33] Remodeling renews existing bone in a sequence of resorption and formation; strain distributions occur during the remodeling process and show a relationship to the activity of osteoblasts and osteoclasts.[32,33] Another important clinical aspect of the presence of microgaps between implant abutments is the incidence of screw loosening and abutment fracture.[34] In recent years, the use of osseointegrated implants to retain single-tooth restorations has gained popularity. Whether the restoration is screw or cement retained on an abutment prepared by the restorative dentist, the possibility of abutment or retaining screw loosening remains a potential problem.[34] In addressing the problem of screw loosening, many manufacturers have attempted to refine the abutments and implant designs to achieve a more predictable method of tightening screws. Within the past few years, cemented prostheses have been introduced that allow prosthetic crowns to be cemented directly on the implant abutment. Cement-retained implant-supported prostheses are routinely used in dentistry. This approach resembles conventional prosthodontic procedures. It has been suggested that cement-retained prostheses have a higher potential of passive fit in light of the fact that the cement space between retainer and abutment could compensate for minor prosthesis misfits.

The results obtained in the present study are interesting because they clarify the dimensions of the microgap in vivo. Microgaps have been found in all the present implants. In clinical practice it is very difficult to reduce the dimensions of this microgap. The presence of voids certainly facilitates the bacterial migration and the presence of bacteria inside the implant, which could be the result of either contamination during the first or second stage of implant placement or transmission of bacteria from the oral environment after prosthesis placement. This phenomenon is directly correlated to the presence of the microgap.

Our results confirm the previously published data that the microgap can be a critical factor for migration of bacteria in the internal portion of implant and in crestal bone resorption.[35–40] Another consideration is that the dimensions of the microgap are unpredictable, variable, and much larger than the size observed in an in vitro study.[17]

Even if the gaps are present at the level of the implant-abutment connection in all implants with screw- and cement-retained abutments, 2 important differences distinguish these 2 groups. First, there is a statistically significant difference in the size of the microgap between cement-retained (mean about 40 μm) and screw-retained (mean about 60 μm) abutments. But the second and most important difference is that in cement-retained abutments the cement completely fills the voids between implant and abutment. These results confirm and expand the data obtained in a previous in vitro study made in our department.[17] Further studies on large series of retrieved implants are necessary to try to improve our understanding of the internal colonization of dental implants by bacteria and the relationship between the microgap and the crestal remodeling and long-term peri-implant tissue health.

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