micro-gap measurements under 3-D X-ray

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ABSTRACT (199 words)

Purpose. The presence of a microgap between implant and abutment could produce a bacterial reservoir which could interfere with the long-term health of the peri-implant tissues. The aim of this paper was to evaluate, by X-ray 3-D microtomography, implant-abutment contact surfaces and microgaps at the implant-abutment interface in different types of implant-abutment connections.

Materials and Methods: A total of 40 implants were used in this *in vitro* study. Ten implants presented a screw retained internal hexagon abutment (Group I), 10 had a Cone Morse taper internal connection (Group II), 10 another type of Cone Morse taper internal connection (Group III), 10 a screwed trilobed connection (Group IV).

Results: In both types of Cone Morse internal connection there was no detectable separation at the implant/abutment in the area of the conical connection, and there was an absolute congruity without any microgaps between abutment and implant. No line was visible separating the implant and the abutment. On the contrary, in the screwed abutment implants numerous gaps and voids were present.

Conclusions: The results of the present study seem to support the hypothesis that length and characteristics of the implant-abutment joint could be a reason for the observed differences in bacterial penetration.

KEY-WORDS: Bacterial leakage, Crestal bone remodelling microgap, Implant-abutment connections, X-ray microtomography.

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Dental implant systems using screw-retained abutments have been clinically used for many decades and their long-term success is well documented[1-3]. A problem associated with this type of implant-abutment connections is the loosening and fracturing of the screws. Screw loosening could be also an indication of an inadequate biomechanical design of the prosthetic reconstructions and/or of occlusal overloading. Implant failures may be divided in biologic, mechanical, iatrogenic, and functional[4]. Implant failures most probably originate from implant overloading, or from bacterial infection of the peri-implant tissues[5-10]. It has been reported that, in implants with a screw-retained abutment, bacteria can penetrate, *in vivo* and *in vitro*, inside the internal hollow portion of the implant because of gaps at the implant-abutment connection[11-13]. It has also been reported that, with screw-retained abutments, the abutment loosening occurs frequently[14-15]. 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[16]. The problem of the microgap between implant and abutment is biological and mechanical. The biological problem is related to the presence of bacteria that have been found in the apical portion of the abutment screw[11,17], and this fact, *in vivo*, could produce a bacterial reservoir which could interfere with the long-term health of the peri-implant tissues[17-41]. The mechanical problem of the microgap is related to micromovements and possible loosening or fracture of screw-retained abutments[42-45]. The internal conical implant-abutment connection is considered to be mechanically more stable, and more tight than flat-to-flat connections or tube-in-tube connections[26,46], and able to provide a better seal[23-25,34-36].

The aim of this paper was to evaluate, with X-ray 3-D microtomography, implant-abutment contact surfaces and microgaps at the implant-abutment interface in different types of implant-abutment connections.

MATERIALS AND METHODS

A total of 40 implants, 10 implants per group, were used in this *in vitro* study. Ten implants presented a screw retained internal hexagon abutment (Group I) (Universal II HI Implacil De Bortoli, Sao Paulo, Brazil), 10 with a Cone Morse taper internal connection (Group II) (Universal II CM Implacil De Bortoli, Sao Paulo, Brazil), 10 Cone Morse taper internal connection (Group III) (ANKYLOS plus, DENTSPLY Implants Manufacturing GmbH, Mannheim, Germany), 10 with a screwed trilobed connection (Group IV) (Replace Select, Nobel Biocare, Gothenburg, Sweden).

All abutments were inserted using the recommended torque values.

Specimen processing

Each sample underwent 5 X-ray microtomography consecutive acquisitions by Skyscan 1072 (SkyScan, Kartuizersweg 3B, 2550 Kontich, Belgium) to measure implant-abutment contact areas of the 3 implant systems considered, and to detect the possible presence of microgaps over and along the whole interface. This innovative investigation technique has made it possible to assess the perfection of connection sealing in a non-destructive, non-invasive, and three-dimensional way[20, 21]. All implants have been resin-embedded in vertical position within a cylinder-shaped mould to avoid motion artifacts. The same acquisition parameters adopted for all sample are as follows:

- rotation step = 0.45°,
- total rotation angle = 180°,
- power source 100 KV / 98 microA,
- filter thickness 1 mm (Al)

Magnification and cross-section pixel size acquisition parameters have been chosen according to the following values:

- Sample 1: magnification at 30X and cross section, pixel size of 9.77 µm;
- Sample 2: magnification at 26X and cross section, pixel size of 11.27 µm;

- Sample 3: magnification at 26X and cross section, pixel size of 11.27 μm;

-Sample 4: magnification at 26X and cross section, pixel size of 11.27 μm.

All images obtained have been processed by a dedicated reconstruction software (CTan), able to reproduce the exact 3D model of each examined implant.

RESULTS

Group I (Implants with screwed abutments)

In the screw-abutment interface numerous gaps (mean 52.3 ± 4.5 μm) were present (Fig. 1), and also in several portions areas where titanium had been teared off from the surface and from the internal threads were detected. Spaces (50 ± 5.2 μm) were observed between the internal portion of the implant and the threads of the screw. In all cases, spaces and damaged areas of the threads could be seen present. In no case a perfect adaptation between the implant and the screwed abutment was observed. The internal volume was 9.304 (mm^3).

Group II (Implants with conical abutment)

There was absolute congruity with no detectable gap in most of the area of the conical connection between implant and abutment. In a few areas, 2-4 μm gaps were present. The area of the conical connection had an extension of 3.305 μm. The internal space volume was 5.014 (mm^3) (Fig. 2).

Group III (Implants with conical abutment)

There was no detectable separation at the implant/abutment in the area of the conical connection, which had an extension of 1798 μm (Fig.3) and showed an absolute congruity without any microgaps between abutment and implant. No line was visible separating the implant and the abutment. The internal space volume was 5.231 (mm^3).

Group IV (Implants with a screwed trilobed connection)

The extension of the contact between implant and abutment was 560 µm. In this area there was a perfect congruity between the conical portion of the abutment and the internal portion of the implant. Gaps were present at other areas of the abutment-implant interface, with the greatest value at 235 microns. The internal volume was 6.396 (mm^3) (Fig.4).

DISCUSSION

The goal in using x-ray micro-CT technique in the current study was to detect spaces and gaps along the implant-abutment connection. Also, this technique made possible the evaluation of the implant-abutment assembly in three dimensions, and this was not possible with conventional radiographic techniques and under Scanning Electron Microscopy. This technique has also made possible to investigate the implant-abutment connection in a non-invasive and non-destructive way[47].

A resorption of the peri-implant crestal bone, especially in the first year after loading, has been reported to occur around dental implants[48-49]. The cause of this resorption is still unknown, but an influence of the bacteria present inside the microgaps and voids located between the implant-abutment assembly has been hypothesized[50-53]. Several experimental studies have demonstrated that when the microgap was moved in a coronal direction, the bone resorption was decreased, while, when it was moved in an apical direction, the bone resorption increased[54-59]. Moreover, it has been reported that, radiographically, in Cone Morse conical internal connection implants, after 1 year, new bone formation was found over the implant shoulder[60-61]. These data have been supported by experimental animal studies and histological studies of human retrieved implants[62-65]. Furthermore, histological studies of the peri-implant soft tissues in human retrieved implants have revealed only a slight inflammatory infiltrate[66-67].

Microleakage at the implant/abutment interface has been shown to occur in all implant systems with variability between the different systems. The presence of a microgap could be due to a not precise machining of the component parts, to excessive torque forces during the insertion of the abutment with a distortion of the path, and not proper male-female distribution[20]. Bacterial colonization of the microgaps and of the internal cavities has been correlated to a poor adaptation of the components[39]. A more exact adaptation of these components plays, apparently, an important role in obtaining a better stability of the implant-abutment assembly[39], and the microgap colonization is potentially related to the precision fit between the implant components, the closing torque values, and the loading forces[22]. Moreover, the presence of a microgap could produce an not favorable distribution of the stress on the connection components[68]. The voids between the implant and abutment components could produce an increase of stresses in the surrounding bone, implant pieces and connection components[20]. Conical Morse taper connections have been shown to be more tight and stable from a biomechanical point of view than flat-to-flat connections[26]. The results of the present study seem, then, to support the hypothesis that the length of the implant-abutment joint could be a reason for the differences in bacterial penetration[28]; in fact, the values of the length for the two types of internal conical connections (Groups II and III) were much higher than those of the other types of connections. In previous *in vitro* studies from our Laboratory, evaluating the microleakage in different types of connections, it was found, in all cases, a much lesser degree of bacterial leakage in internal conical connections[23-25]. Furthermore, the 3-D X-ray microtomography helped to confirm the fact that, probably, the microgap had not an uniform width between the external and the internal segments of the assemblies[38]. The microgap could, then, describe an incomplete or sinuous journey through the implant-abutment interface[38]. A recent review of the literature reported that external hexagon implants had the greatest bacterial leakage, followed by internal trilobe, internal hexagon, and internal taper configurations[40]; the present results could help to explain these findings.

Finally, the findings of the present study were in agreement with previously reported data that, in internal Cone Morse connection implants, a few mm of the conical portion of the abutment were in close contact with the internal surface of the implant[46], and the microgap was difficult to distinguish because the two parts appeared to be very well adapted[40]. Of importance could be also the fact that the internal volume of the microgaps and voids present at the implant-abutment interface and in the internal portion of the implants was much lesser in the two types of internal Cone Morse conical connection implants.

CONCLUSION

In conclusion, this X-ray 3-D non-destructive and non-invasive technique could be very helpful in evaluating the different types of implant-abutment connections and in trying to better understand the different bacterial leakage found and reported in the literature for the various implants and crestal bone resorption[69].

DISCLOSURE: The authors claim to have no financial interest, either directly or indirectly, in the products or information listed in the paper.

APPROVAL

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LEGENDS

Fig. 1 Numerous gaps were present at the level of the implant-abutment interface. In no case a perfect adaptation between the implant and the screwed abutment was observed.

Fig. 2 In no case a perfect adaptation between the implant and the screwed abutment was observed.

Fig. 3 An absolute congruity without any microgaps was observed between abutment and implant. No visible line separated the implant from the abutment.

Fig. 4 Gaps were present in several portions of the abutment-implant interface.