The mucosal attachment at different abutments
An experimental study in dogs


Abstract. The present experiment was performed to examine if the material used in the abutment part of an implant system influenced the quality of the mucosal barrier that formed following implant installation. 5 beagle dogs were included in the study. The mandibular premolars and the 1st, 2nd and 3rd maxillary premolars were extracted. Three fixtures of the Brånemark System® were installed in each mandibular quadrant (a total of 6 fixtures per animal). Abutment connection was performed after 3 months of healing. In each dog the following types of abutments were used: 2 “control abutments” (c.p. titanium), 2 “ceramic abutments” (highly sintered Al2O3), 1 “gold abutment”, and 1 “short titanium abutment”. This “short titanium abutment” was provided with an outer structure made of dental porcelain fused to gold. Following abutment connection a plaque control program was initiated and maintained for 6 months. The animals were sacrificed and perfused with a fixative. The mandibles were removed and each implant region was dissected, demineralized in EDTA and embedded in EPON®. Semithin sections representing the mesial, distal, buccal and lingual aspects of the peri-implant tissues were produced and subjected to histological examination. The findings from the analysis demonstrated that the material used in the abutment portion of the implant influenced the location and the quality of the attachment that occurred between the periimplant mucosa and the implant. Abutments made of c.p. titanium or ceramic allowed the formation of a mucosal attachment which included one epithelial and one connective tissue portion that were about 2 mm and 1-1.5 mm high, respectively. At sites where abutments made of gold alloy or dental porcelain were used, no proper attachment formed at the abutment level, but the soft tissue margin receded and bone resorption occurred. The abutment fixture junction was hereby occasionally exposed and the mucosal barrier became established to the fixture portion of the implant. It was suggested that the observed differences were the result of varying adhesive properties of the materials studied or by variations in their resistance to corrosion.

Key words: abutment; biomaterials; dogs; histometry; implant; peri-implant mucosa

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The mucosa that surrounds dental implants made of commercially pure (c.p.) titanium has been studied in man as well as in different animal models (Addell et al. 1986, Berglundh et al. 1991, 1992, 1994, Buser et al. 1992, Ericsson et al. 1992, 1995, Abrahamsson et al. 1996, Berglundh & Lindhe 1996, Cochran et al. 1997). It was demonstrated that the portion of the mucosa that faces the surface of the titanium abutment can be divided into 2 different zones; one marginal zone that harbors a junctional epithelium and one more apical zone that is comprised of a fiber rich connective tissue (Berglundh et al. 1991, Buser et al. 1992, Abrahamsson et al. 1996). From experiments in vitro, Gould et al. (1981), and in vivo Gould et al. (1984) concluded that the junctional epithelium of the peri-implant mucosa via hemidesmosomes is attached to the titanium surface, while Berglundh et al. (1991, 1994) and Buser et al. (1992) from experiments in the dog suggested that the connective tissue in the interface zone has the character of a scar (sparse in cells and vascular structures but rich in collagen fibers) which is firmly attached to the abutment. The importance of this epithelial/connective tissue attachment for the maintenance of osseointegration was emphasized by, e.g., Berglundh et al. (1992), Abrahamsson et al. (1996) and Berglundh & Lindhe (1996).
In attempts to improve esthetics and to facilitate technical processing, materials other than c.p. titanium, e.g., gold alloys, ceramics and dental porcelain have been tried in the abutment part of different implant systems. Knowledge, however, regarding soft tissue healing and characteristics of the mucosal attachment to such non-titanium abutment materials is essentially lacking.

The aim of the present experiment was to examine how the material used in the abutment part of a 2-stage implant system influenced the composition and quality of the mucosal barrier that formed following abutment connection.

Material and Methods

5 beagle dogs, about 1 year old, were included in the study. At the start of the experiment the mandibular premolars (4P4, 3P3, 2P2, 1P1) and the 1st, 2nd and 3rd maxillary premolars (4P4, 3P3, 2P2, 1P1) were extracted. After 3 months of healing, 3 fixtures of the Brånenmark System® (Nobel Biocare AB, Göteborg, Sweden: 7x3.75 mm) were installed in each mandibular quadrant (a total of 6 fixtures per animal). Abutment connection was performed after another 3 months. The abutments used and their position were the following (Fig.1).

- 2 (1 on each side) “control abutments” (standard abutment, Brånenmark System®, Nobel Biocare AB, Göteborg, Sweden) made of commercially pure titanium (height 5.5 mm, Ø 4.5 mm).
- 2 (1 on each side) “ceramic abutments” (highly sintered: 99.5% Al2O3); CerAdapt® (Nobel Biocare AB, Göteborg, Sweden: height 4.0 and 5.5 mm, Ø 4.5 mm).
- 1 “gold abutment” (Nobel Biocare AB, Göteborg, Sweden), the alloy contained Au: 60%, Pt: 19%, Pd: 20% and Ir: 1% (height 4.0 mm, Ø 4.5 mm).
- 1 “short titanium abutment” (Estheti-ConeTM, Brånenmark System®, Nobel Biocare AB, Göteborg, Sweden). The “short titanium abutment” (height 1.0 mm, Ø 4.5 mm) was provided with a super structure, made of dental porcelain fused to gold, which gave an overall geometry and dimension similar to the control, gold- and ceramic abutments (height 4.0 mm and Ø 4.5 mm).

All abutments were given final surface treatment by the manufacturer (Nobel Biocare AB, Göteborg, Sweden).

The abutments were tightened with a Torque Controller (Nobel Biocare AB, Göteborg, Sweden). This device was set at 20 Ncm when the “control”, the “gold” and the “short titanium” abutments were installed and set at 32 Ncm when the “ceramic abutments” were placed.

Following abutment connection, a 6-month period of plaque control, including daily cleaning with toothbrush and dentifrice, was initiated. At the end of this period, a clinical examination including assessment of plaque and soft tissue inflammation was performed.

The distances between the landmarks were measured in a Leica DM-RBE® microscope (Leica, Germany) equipped with an image system Q-500 MC® (Leica Germany).

Fig. 1. Schematic drawing illustrating the various landmarks used for the histometric measurements. PM - the marginal portion of the periimplant mucosa, aJE - the level of the apical termination of the junctional epithelium, B - the marginal level of bone to implant contact, A/F - the abutment/fixture borderline.

Histometric analysis

In each section, histometric measurements were performed to describe the vertical dimension of the marginal peri-implant tissues adjacent to the implant. The following landmarks were identified and used for the linear measurements (Fig. 1): PM - the marginal position of the peri-implant mucosa, aJE - the apical termination of the junctional epithelium, B - the marginal level of bone to implant contact; A/F - the level of the abutment/fixture border.

The distances between the landmarks were measured in a Leica DM-RBE® microscope (Leica, Germany) equipped with an image system Q-500 MC® (Leica, Germany).

Morphometric analysis

The morphometric measurements were restricted to a 80 μm wide zone of the connective tissue lateral to the abutment surface and between aJE and A/F. The analysis included assessments of the content of collagen (Co), vessels (V), fibroblasts (Fi), leukocytes (Leu) and residual tissue (R; the remaining tissue constituents such as nerves and matrix components lumped together) and was carried out in a Leica DM-RBE® microscope (Leica, Germany) equipped with an image system Q-500 MC® (Leica, Germany). A lattice comprising 100 light points (Schroeder & Münzel-Pedrazzoli 1973) was superimposed over the connective tissue area at a magnification of ×1000.
Statistical analysis

For each dog, mean values from measurements made at the mesiobuccal, distobuccal, mesiolingual and distolingual units were calculated for the various dimensions and for the different types of abutment. Differences between the various abutment sites were analyzed using the Student t-test for paired observations. The null hypothesis was rejected at $p<0.05$.

Results

Clinical observations

Healing following fixture installation and subsequent abutment connection was uneventful. During the plaque-control period a minor fracture occurred at 2 of the "ceramic abutments". The fractures involved about 2 mm of the coronal part of the abutment and did not interfere with the adjacent mucosa. The clinical examination performed at the end of the study disclosed that all abutment surfaces in all five dogs were virtually free from plaque and that the peri-implant mucosa at all implant sites was devoid of clinical signs of inflammation (Fig. 2). Marked soft tissue recession, resulting in an exposure of the abutment/fixture junction was observed at the mid-buccal and/or mid-lingual aspects at 3 out of 5 of the "gold abutment" sites.

Gross histological and histometric observations

The histological landmarks could easily be identified in all sections. The results of the histometric measurements are reported in Table 1.

Control abutment (Titanium)

The peri-implant mucosa adjacent to the "control abutment" was comprised of one epithelial and one connective tissue portion. The connective tissue portion, located between aJE and B ("zone of connective tissue integration"), was characterized by a dense collagenous network including few vascular structures and scattered fibroblasts and inflammatory cells (Fig. 2). The mucosa was lined by a keratinized epithelium which was continuous with thin junctional epithelium facing the implant. The height of the junctional epithelium (PM – aJE) was about 2 mm. The most marginal position of bone to implant contact (B) was located at a distance of 0.78 mm "apical" of A/F and 1.3 mm "apical" of aJE. The distance between the mucosal margin (PM) and A/F was on the average 2.54 mm. An inflammatory cell infiltrate was consistently identified in the connective tissue at the level of A/F. This infiltrate had an "apico-coronal" dimension of about 0.6 mm and occupied an area of about 0.10 mm$^2$.

Ceramic abutment

The peri-implant mucosa at the "ceramic abutment" had many features in common with the soft tissue at the "control abutment" sites. Thus, the mucosal attachment comprised a 2 mm long junctional epithelium and a zone of connective tissue that was about 1.3 mm high (Fig. 2). The distance between A/F and B on the average 0.80 mm and the distance between PM and A/F was 2.56 mm. In all sections, an inflammatory cell infiltrate was observed in the connective tissue at the level of A/F. This lesion was larger than the corresponding lesion identified at the "control abutment" sites. Thus, the "apico-coronal" dimension and the size of the ICT were about 0.8 mm and 0.18 mm$^2$, respectively.

Gold abutment

The peri-implant mucosa surrounding the "gold abutment" (Fig. 4) differed in several aspects from the mucosa at the control sites. Thus, the dimension PM – B at the "gold abutment" sites was significantly smaller than the corresponding dimension at the control sites: 2.55 mm versus 3.32 mm. Consequently, the length of the junctional epithelium and the height of the zone of connective tissue attachment were consistently smaller at the "gold abutment" than at the "control abutment" (1.75 mm versus 2.04 mm and 0.79 mm versus 1.28 mm respectively). B was located a distance of 1.80 mm "apical" of A/F, i.e. about 1 mm further "apical" compared to its location at the "control abutment". This difference was statistically significant. The distance PM – A/F was also significantly smaller at the "gold abutment" (0.75 mm) than at the control sites (2.54 mm).

Short titanium abutment

The "short titanium abutment" was surrounded by a mucosa the height of which was smaller than the corresponding soft tissue at the control sites: 2.99 mm versus 3.32 mm. Also the length of the junctional epithelium and the height of the connective tissue attachment were somewhat smaller than the corresponding dimensions at the control sites: 1.81 mm versus 2.04 mm and 1.19 mm versus 1.28 mm, respectively. Landmark B was located a distance of 1.26 mm "apical" of A/F, i.e. about 0.5 mm more "apical" than at the control sites. This difference was statistically significant. The distance P – A/F was at the "short titanium abutment" sites significantly smaller than at the control sites (1.73 mm and 2.54 mm, respectively). The connective tissue compartment lateral to A/F and to the junctional epithelium (Fig. 2), consistently harbored an inflammatory cell infiltrate. The "apico-coronal" dimension of this lesion was about 0.5 mm and the size was about 0.07 mm$^2$.

| Table 1. Vertical dimensions (mm) of the peri-implant soft tissue components |
|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
|                       | PM-B                  | PM-aJE                 | aJE-B                   | PM-A/F                 | A/F-B                   |
| (mm)                  | mean                   | SD                     | mean                   | SD                     | mean                   | SD                     |
| control               | 3.32                   | 0.24                   | 2.04                   | 0.22                   | 1.28                   | 0.11                   | 2.54                   | 0.35                   | 0.78                   | 0.17                   |
| ceramic               | 3.36                   | 0.26                   | 2.01                   | 0.44                   | 1.34                   | 0.33                   | 2.56                   | 0.22                   | 0.80                   | 0.16                   |
| gold                  | 2.55*                  | 0.28                   | 1.75                   | 0.20                   | 0.79                   | 0.31*                  | 0.75*                  | 0.44                   | 1.80*                  | 0.21                   |
| short titanium        | 2.99                   | 0.31                   | 1.81                   | 0.36                   | 1.19                   | 0.38                   | 1.73*                  | 0.43                   | 1.26*                  | 0.31                   |

Results from the histometric measurements; PM: the marginal portion of the peri-implant mucosa, aJE: the level of the apical termination of the junctional epithelium, A/F: the abutment/fixture borderline, B: the marginal level of bone to implant contact. Mean values and standard deviations (SD). * Indicates statistically significant difference versus Control (titanium). $P$-value $< 0.05$. 

Mucosal attachment at abutments 723
Table 2. Results from the morphometric measurements.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th></th>
<th>Ceramic</th>
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<tr>
<td>(%)</td>
<td>mean</td>
<td>SD</td>
<td>mean</td>
<td>SD</td>
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<tr>
<td>Co</td>
<td>84.0</td>
<td>2.9</td>
<td>82.2</td>
<td>4.4</td>
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<tr>
<td>V</td>
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<td>4.3</td>
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<tr>
<td>Fi</td>
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<td>1.5</td>
<td>7.3</td>
<td>1.0</td>
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<tr>
<td>Leu</td>
<td>1.3</td>
<td>1.0</td>
<td>2.5</td>
<td>1.6</td>
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<tr>
<td>R</td>
<td>3.5</td>
<td>0.5</td>
<td>3.9</td>
<td>0.7</td>
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</table>

The volume % of the connective tissue occupied by collagen (Co), vascular structures (V), fibroblasts (Fi), leukocytes (Leu) and residual tissue (R). Mean values and standard deviations (SD).

Morphometric observations

The morphometric analysis of the peri-implant mucosa was restricted to the “control abutment” and the “ceramic abutment” sites. At the “gold abutment” and the “short titanium abutment” sites, the mucosal margin during healing consistently receded. Hence, the connective tissue component of the mucosal attachment became located at the fixture which at all experimental sites was made of c.p. titanium.

The volume fraction of the connective tissue occupied by collagen, varied between 84% and 82% at the “control abutment” and the “ceramic abutment” sites (Table 2). Fibroblasts made up about 7% and vascular structures about 4%. Only a few scattered inflammatory cells could be identified in the zone of connective tissue attachment.

Discussion

The present experiment demonstrated that the material used in the abutment portion of the implant was of decisive importance for the quality of the attachment that occurs between the mucosa and the implant. Hence, abutments made of c.p. titanium or highly sintered aluminum based ceramic (Al$_2$O$_3$) (i) established similar conditions for mucosal healing to the abutment surface and (ii) allowed the formation of an attachment that included one epithelial and one connective tissue portion that were about 2 mm and 1-1.5 mm high.

On the contrary, at sites where abutments made of gold alloy or dental porcelain were installed at the second stage surgery, no proper attachment seemed to form at the abutment level but the soft tissue margin receded and bone resorption occurred. The abutment fixation was hereby occasionally exposed and the mucosal “seal” was established to the fixture portion of the implant.

The finding that the mucosal attachment that formed to an abutment made of c.p. titanium was comprised of one zone of epithelium (about 2 mm) and one zone of collagen rich/cell poor connective tissue (about 1-1.5 mm) is consistent with data previously reported from similar experiments in the dog (Berglundh et al. 1991, 1992, Ericsson et al. 1996, Abrahamsson et al. 1996, Cochran et al. 1997). The current findings also confirm data by Berglundh & Lindhe (1996) who in the beagle dog model studied the soft tissue attachment that formed at sites with a thin (about 2 mm) mucosa. The authors reported that during healing following abutment connection at such sites bone resorption occurred (about 1.5 mm) to allow the formation of a mucosal barrier that included both epithelium (2 mm) and connective tissue (1.3 mm).

The observation that the “ceramic abutment” established healing conditions similar to those at the control abutment confirms findings previously reported from animal experiments and clinical trials using so-called single crystal sapphire implants (McKinney et al. 1985, Hashimoto et al. 1988, 1989, Akagawa et al. 1989, Fartash et al. 1990, Arvidsson et al. 1991). It was suggested from both light- and electron microscopic examinations that the junctional epithelium that forms at the abutment part of such Al$_2$O$_3$ based implants has many features in common with the dento-epithelial junction at teeth (McKinney et al. 1985, Fartash et al. 1990) and that the Al$_2$O$_3$ material was inert (i.e. showed no release of aluminum in e.g. aggressive acidic test solutions) and bioinert (i.e. showed no cell toxicity, minimal foreign body reaction and allowed cell proliferation on its surface) (Arvidsson et al. 1991). Arvidsson et al. (1996) compared the peri-implant mucosa at Branemark® type implants and the mucosa that formed at single crystal sapphire Al$_2$O$_3$ implants. Soft tissue biopsies were retrieved from human volunteers and examined by histological means. The mucosal units that were present at the 2 implant systems had a similar composition regarding both epithelial and various connective tissue elements. This finding is supported by observations made in the current study.

An important observation made in the present experiment relates to the apparent inability of the gold alloy to promote a mucosal healing that includes a zone of connective tissue attachment or “connective tissue integration” (Berglundh et al. 1991). On the contrary, during healing the mucosal margin at the...
gold abutment sites consistently receded “apically” and was at the end of the study in 3 out of 5 cases found on the fixture part of the implant. At these 3 abutment sites, the entire mucosal attachment (i) occurred to the titanium surface of the fixture, and (ii) included one zone of epithelium and one zone of connective tissue. At the 2 remaining non-exposed gold abutment sites, a pocket epithelium made up the mucosal lining at the abutment level, while the mucosal attachment was established apical of the abutment/fixture junction. In order to allow for the formation of a mucosal barrier (i.e. zone of junctional epithelium and connective tissue) at such sites, substantial resorption of marginal bone tissue occurred. This observation is an agreement with Berglundh & Lindhe (1996) who concluded from an experiment in the dog that a minimum amount of soft tissue attachment (epithelium and connective tissue) to titanium is required and if not available, marginal bone resorption will occur to accommodate this attachment.

The validity of this concept is supported by findings made at the “short titanium abutment” sites. At such sites the available titanium surface of the abutment was only 1 mm, and, hence, insufficient for a properly dimensioned mucosal attachment. As a result, significant amounts of bone resorption occurred at such sites during healing. In this context, however, it should be observed that in the present experiment the degree of bone resorption was more pronounced at the gold abutment than at the “short titanium abutment” sites (1.80 mm vs. 1.26 mm).

The finding that the gold alloy abutments failed to properly interact with the connective tissue is in agreement with findings recently reported in a study by Thomsen et al. (1997). They studied the interface between cortical bone and implants made of gold, zirconium and titanium and reported that the amount of bone formed within the threads of the screw type fixture tested, as well as the degree of bone to implant contact was smaller at gold than at titanium and zirconium implants. Furthermore, areas of soft connective tissue including multinuclear cells and macrophages were observed more frequently at gold implants than at implants made of titanium and zirconium.

It is suggested that the differences reported by Thomsen et al. (1997), and also observed in the present experiment, regarding the tissue interaction with the various implant surfaces may be due to divergence in the basic bio-adhesive properties for the materials studied. Thus, the bio-adhesive properties are known to be comparatively poor for metals but more optimal for ceramics and ceramic-like materials (e.g. titanium dioxide) (for review, see Meyer et al. (1991). It is furthermore commonly accepted that ceramics and titanium dioxide are more resistant to corrosion than gold alloys. In other words, the surface layers of titanium and ceramics are chemically more stable (Handbook of Chemistry and Physics) and therefore will allow cells to grow in contact with the surface.

Finally, in all specimens representing the “control abutment” and the “ceramic abutment” sites, infiltrates of inflammatory cells were consistently present in the mucosal lateral to the abutment/fixture junction. This so called “abutment ICT” was previously described by, e.g., Ericsson et al. (1995) and Abrahamsson et al. (1998) as the host response to bacterial contamination of the internal portion of the Branemark System® of dental implants. In the present experiment the “abutment ICT” was somewhat larger in the ceramic abutment sites than in the controls. It is likely that this difference can be explained by the presence of a larger microgap between the ceramic abutment and the fixture than between the titanium abutment and the fixture at the control site.

Acknowledgments

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Zusammenfassung

Das Attachment der Mukosa bei verschieden en Implantatpfosten. Eine experimentelle Studie an Hunden

Das hier beschriebene Experiment wurde vorgenommen um zu untersuchen, ob der Werkstoff eines Implantatpfostens die Qualität der Mukosabarriere beeinflucht, die sich nach dem Einbringen des Implantats bildet. 5 Beagle Hunde wurden in die Studie einbezogen. Die Unterkieferprämolaren und der 1., 2. und 3. Oberkieferprämolar wurden extrahiert. 3 Fixuren des Bränemark System® wurden in jeden Unterkieferquadranten eingebracht (insgesamt 6 Fixuren pro Versuchs-

Résumé

L’attache muqueuse au niveau de différents piliers. Une étude expérimentale sur le chien

L’étude présente a été réalisée pour examiner si le matériel utilisé dans la partie pilier d’un système implantaire influençait la qualité de la barrière muqueuse qui se formait après l’installation de l’implant. 5 chiens Beagle ont été inclus dans cette étude. Les prémolaires mandibulaires et les premières, deuxième et troisièmes prémolaires maxillaires ont été avulsées. 3 implants ad modum Bränemark ont été placés dans chaque quadrant mandibulaire totalisant 6 implants par animal. La connexion du pilier a été effectuée après 3 mois de guérison. Chez chaque chien les types suivants de piliers ont été utilisés: 2 piliers contrôles (titane commercialement pur), 2 piliers en céramique (99,5% Al₂O₃), un pilier en or et un pilier en titane court (structure externe faite en porcelaine dentaire sur or). Après la connexion du pilier un programme de contrôle de la plaque dentaire a démarré et a été maintenu durant six mois. Les ani- maux ont été tués, les mandibules ôtées et
chaque région implantaire a été disséquée, déminéralisée dans l'EDTA et incluse dans l'EPON®. Des coupes semi- fines représentant les aspects métaux, distaux, vestibulaires et linguaux des tissus paroimplantaires ont été produites et soumises à l'examen histologique. Les découvertes de cette analyse ont démontré que le matériel utilisé dans la portion pilier de l'implant influençait la localisation et la qualité de l'attache qui se faisait entre la muqueuse paroimplantaire et l'implant. Les piliers faits en titane commercialement pur ou en céramique donnaient nuisances à la formation d'une attache muqueuse qui comportait une partie épithéliale et une partie de tissu conjonctif qui étaient respectivement d'environ 2 mm et de 1-1,5 mm de hauteur. Au niveau des sites où les piliers étaient fabriques en or ou en porcelaine aucune attache correcte ne se formait au niveau du pilier mais le tissu mou marginal avait subi une récession et s'accompagnait d'une résorption osseuse. La jonction implant-pilier était occasionnellement mise à nu et la barrière muqueuse était établie sur la portion de l'implant lui-même. Les différences observées seraient le résultat de propriétés d'adhésion différentes des matériaux étudiés ou dues aux variations dans leur résistance à la corrosion.

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