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Influence of microgap location and configuration on the periimplant bone morphology in submerged implants. An experimental study in dogs

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Abstract

Objectives: The vertical location of the implant-abutment connection influences the periimplant bone morphology. It is unknown, however, whether different microgap configurations cause different bone reactions. Therefore, in this study the bone morphologies of two different implant systems were compared.

Material and methods: Three months after tooth extraction in eight mongrel dogs, two grit-blasted screw implants with internal Morse taper connection (ANK group) were placed on one side whereas the contralateral side received two oxidized screw implants with external hex (TIU group). One implant on each side was placed level with the bone (equicrestal), the second implant was inserted 1.5 mm below bone level (subcrestal). After 3 months the implants were uncovered. Three months after stage two surgery, histometrical evaluations were performed in order to assess the periimplant bone levels (PBL), the first bone-to-implant contact points (BICP), the width (HBD) and the steepness (SLO) of the bone defect.

Results: All implants osseointegrated clinically and histologically. Bone overgrowth of the microgap was seen in ANK implants only. No significant differences between ANK and TIU could be detected in neither vertical position for PBL and BICP. However, a tendency in favor of ANK was visible when the implants were placed subcrestally. In the parameters HBD (ANK equicrestal −0.23 mm; TIU equicrestal −0.51 mm; ANK subcrestal +0.19 mm; TIU subcrestal −0.57 mm) and SLO (ANK equicrestal 35.36°; TIU equicrestal 63.22°; ANK subcrestal 20.40°; TIU subcrestal 44.43°) more pronounced and significant differences were noted.

Conclusions: Within the limits of this study, it is concluded that different microgap designs cause different shapes and sizes of the periimplant ('dish-shaped') bone defect in submerged implants both in equicrestal and subcrestal positions.

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The more predictable implant therapy has become in recent years (Pjetursson et al. 2004), the more interest has been attributed to parameters which may modulate the interactions between implant and host (Wallace & Froum 2003; Graziani et al. 2004; Hinode et al. 2006; Shalabi et al. 2006). One of the major foci of such interest is the implant-abutment connection type (Piermatti et al. 2006). Whereas most implant systems nowadays seem to prefer internal to external connections, the tightness and stability of the different connection types seems to influence microbial leakage (Dibart et al. 2005) and mechanical stability (Zipprich et al. 2007) of the connected parts which in turn may exert an influence on the periimplant tissue reactions.

The connection line between implant and abutment, the so-called microgap, has been investigated intensively during the last 10 years. From a series of radiographical and histological studies in experimental set-ups, it was concluded that in a butt joint connection (a) the radiographical bone-to-implant contact develops a distance of 2 mm from the microgap irrespective of the vertical location of the microgap relative to the surrounding bone level (Hermann et al. 1997), (b) the histological bone-to-implant contact keeps a distance of 1.3–2.6 mm from the microgap depending on the location of the microgap relative to the surrounding bone level (Hermann et al. 2000, 2001), (c) the microgap size itself does not influence the amount of periimplant bone resorption, unless micromovement becomes an additional factor (Hermann et al. 2001; King et al. 2002), and (d) the healing mode (submerged vs. non-submerged) does not influence the amount of the periimplant bone resorption during the healing phase of an implant (Ericsson et al. 1996). These findings have been clinically observed for more than 20 years as 'dish-shaped' defects around the microgap and termed 'periimplant bone remodelling (down to the first thread)'. They were considered in the implant success criteria from 1986 (Albrektsson et al. 1986) and reinforced in 1998 (Zarb & Albrektsson 1998) by stating that the amount of periimplant bone loss was not considered relevant to an implant's success before the first year of loading has passed.

From a functional viewpoint the amount of periimplant bone loss during the healing phase might not be crucial to the overall success or survival rate of an implant. From an esthetic viewpoint, however, loss of periimplant bone always might involve loss of periimplant soft tissue structures because bony support of soft tissues is considered a key factor in periimplant soft tissue stability.

It was the aim of this animal study to histometrically investigate the influence of different vertical microgap locations on the periimplant bone morphology in two different implant-abutment connection types.

Material and methods

General

The study protocol of this investigation was approved by the Ethical Committee for Animal Investigations of the Universidade Estadual Paulista 'Júlio de Mesquita Filho', Campus de Araçatuba, Brazil. All surgical interventions were carried out under general anesthesia using atropine sulphate, xylazine, tiletamine/zolazepam and lidocaine with epinephrine. In addition, antibiotics (espiramizine/metronidazol) and NSAIDs (flunixine/meglumine) were applied perioperatively. Wound healing was accompanied by chlorhexidindigluconate rinsing three times per week.

Sample size calculations were made based on the assumption that a mean difference of 0.5 mm should be detected at a significance level of 0.05 and a desired power of 80%.

Surgery

In this study eight mongrel dogs were used. Before the beginning of the experiment all premolars (P1–P4) and the first molar (M1) were extracted on both sides of the mandible. The extraction sockets were left untreated for 3 months. Then mucoperiosteal flaps were raised, the mandibular ridges were flattened with burs to a bucco-lingual width of 6–7 mm, and osteotomies for two implants on each side were drilled according to the manufacturers' protocols. On one side two implants with a grit-blasted surface and an internal Morse-taper connection were inserted (Ankylos® A8, Dentsply Friadent; diameter 3.5 mm; length 8 mm; ANK group) (Fig. 1) in a way that the implant shoulder of one implant was located at the surrounding bone level (equicrestal position) (Fig. 3), whereas the implant shoulder of the second implant was put 1.5 mm below bone level (subcrestal position) (Fig. 4). The same was carried out on the contralateral side but screw-type implants with an oxidized surface and an external hex were used instead (TiUnite® Branemark, Nobel Biocare; diameter 3.75 mm; length 8.5 mm; TIU group) (Fig. 2). Left and right sides were alternated between implant systems as well as anterior and posterior positions between subcrestal and equicrestal groups. However, on each side only one implant system was used, and vertical implant positions were the same on both sides of the mandible. The flaps were sutured and the implants were left submerged with their cover screws in place for 3 months. Sutures were removed after 1 week.

After 3 months of healing the implants were surgically uncovered. The stage two

Fig. 1. Insertion of an implant of the ANK group. Apical to the black insertion mount the smooth collar of the implant can be seen followed by the grit-blasted surface of the implant body.

Fig. 2. Insertion of an implant of the TIU group. The implant has a smooth shoulder with the external hexagon. Apically the oxidized surface of the implant body can be seen.

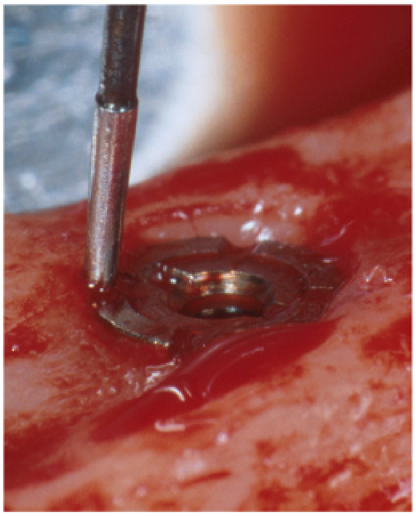

Fig. 3. Equicrestal insertion of an implant of the ANK group.

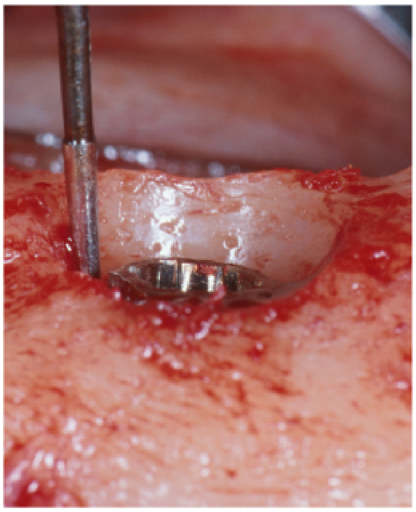

Fig. 4. Subcrestal insertion of an implant of the TIU group.

procedure was carried out minimally invasive, i.e. no flaps were elevated in order not to expose periimplant bone tissue. Instead, small incisions or soft tissue excisions were performed so that the cover screws could be removed and replaced by healing abutments. The implants with healing abutments attached were then maintained in the oral cavity for another 3 months (Figs 5 and 6).

Histology

After a total healing time of 6 months the animals were sacrificed and two to three mesio-distal ground sections were made from each implant and stained with toluidine blue solution (Donath & Breuner 1982).

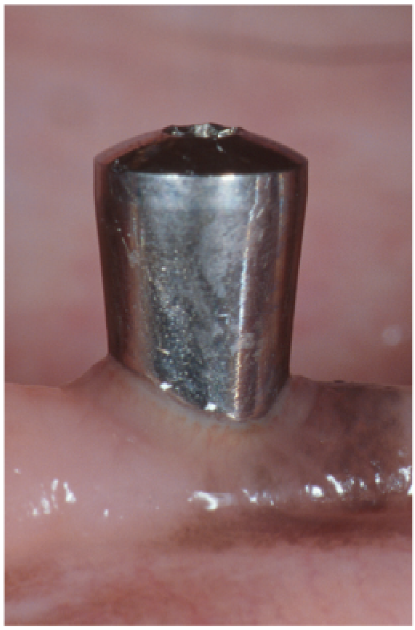

Fig. 5. After 6 months of healing (3 months submerged plus 3 months non-submerged) an implant of the ANK group presents with healthy periimplant soft tissue conditions.

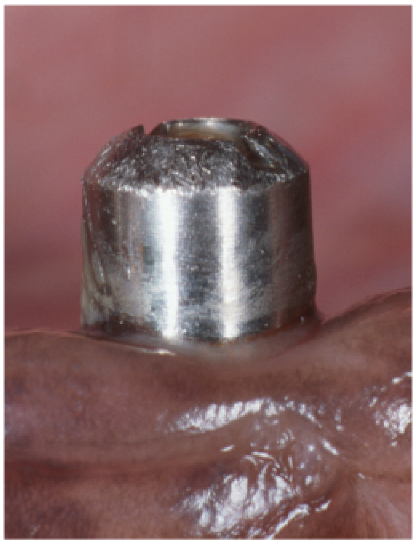

Fig. 6. After 6 months of healing (3 months submerged plus 3 months non-submerged) an implant of the TIU group presents with healthy periimplant soft tissue conditions.

The following parameters were assessed histometrically (Fig. 7):

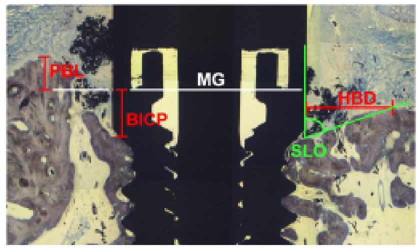

Fig. 7. Example of parameter assessement. For the definitions and abbreviations of the parameters please see material and methods. White line (MG) represents microgap level.

(1) periimplant bone level (PBL): vertical distance between the most coronal point of the periimplant bone and the implant shoulder; expressed as positive value, if the periimplant bone was located coronally to the implant shoulder,
(2) bone-to-implant contact point (BICP): vertical distance between the most coronal BICP and the implant shoulder; expressed as negative value, if the BICP was located apically to the implant shoulder,
(3) horizontal bone distance (HBD): horizontal distance between the most coronal point of the periimplant bone and a vertical line along the outer implant surface; expressed as negative value, unless bone was grown onto the implant shoulder,
(4) periimplant bone slope (SLO): angle between a line extending along the periimplant bone defect and a vertical line along the outer implant surface.

Statistics

Each parameter was measured on both the mesial and the distal aspect of a histological section and summarized as a mean per section. These means of the two to three sections available per implant were summarized as a mean per implant. Thus the statistical unit was the implant (equal to the animal). Comparisons between implant systems within the same vertical group and between vertical groups within the same implant system were made by using paired *t*-tests.

Results

Clinical results

Healing was uneventful, and all implants were clinically osseointegrated and immobile at stage two surgery and at sacrifice. The periimplant tissue condition was characterized by health or occasional slight inflammation.

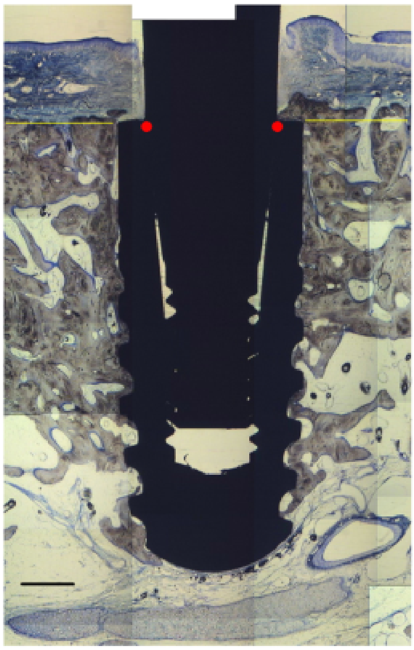

Fig. 8. Implant of the equicrestal ANK group. Note the close proximity of the periimplant bone and the microgap. The bone has grown onto the implant shoulder and is in histological contact with the healing abutment on the right aspect. Red dots indicate microgap. Yellow line shows bone level at implant placement. Black bar represents 1 mm.

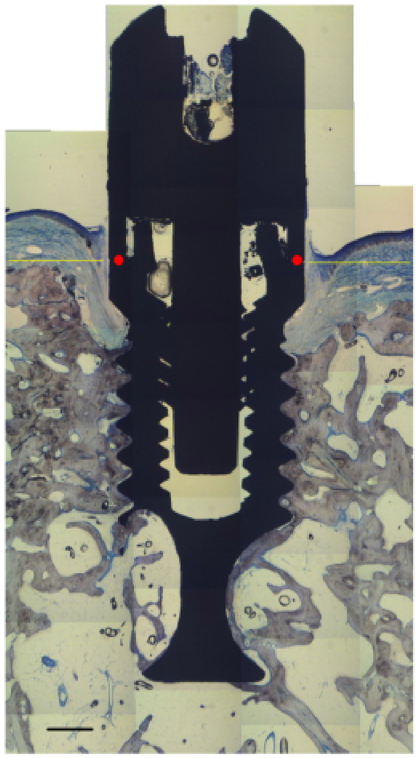

Fig. 9. Implant of the equicrestal TIU group. Note the typical 'dish-shaped' bone defect extending to the first implant thread. Red dots indicate microgap. Yellow line shows bone level at implant placement. Black bar represents 1 mm.

Fig. 10. Implant of the subcrestal ANK group. Note the narrow 'funnel' establishing close proximity between the periimplant bone and the healing abutment. The bone has grown onto the implant shoulder and established histological contact to the healing abutment on both sides. Red dots indicate microgap. Yellow line shows bone level at implant placement. Black bar represents 1 mm.

Histological findings

The histological sections showed well-osseointegrated implants both in the ANK group and in the TIU group regardless of the vertical insertion depth of the implants (Figs 8–11). The PBLs were coronally to the implant shoulder, when the implants were placed subcrestally (Figs 10 and 11). Usually the first bone-to-implant contact was located apically to the implant shoulder. Exceptions from this finding were visible only in the ANK group (especially in the subcrestally placed implants) where bone tissue was found overgrowing the microgap and establishing the first bone-to-implant contact on the healing abutment (Figs 8 and 10). The shape of the periimplant bone defect was extended more horizontally in the TIU group (Figs 9 and 11), whereas the 'funnel' was narrower in the ANK group with frequent bone growth onto the implant shoulder of subcrestally placed implants of the ANK group (Fig. 10).

Histometrical measurements

The histometrical means, standard deviations and *P*-values are summarized in Table 1 for the equicrestally placed implants and in Table 2 for the subcrestally placed implants. The results are depicted graphically in Figs 12 and 13. Statistically significant differences between the ANK and the TIU group were found for the parameter SLO in both equicrestal and subcrestal implants and for the parameter HBD in subcrestally placed implants. Statistical comparisons of the different vertical positions (equicrestal vs. subcrestal placement) within the same implant system regarding the parameters BICP, HBD and SLO revealed significant differences for BICP ($P<0.05$) and HBD ($P<0.05$) in the ANK group, and for BICP ($P<0.001$) and SLO ($P<0.01$) in the TIU group. The parameter PBL was not compared because it seemed logical that differences in the height of the periimplant bone exist, if implants are inserted in different vertical positions.

Discussion

In both implant systems a loss of periimplant bone height was noted, when the implants were placed equicrestally (ANK group −0.69 mm, TIU group −0.91 mm). In addition, the first bone-to-implant contact was located approximately 1.5 mm apical to the implant shoulder. No significant differences were found between the two systems regarding the parameters PBL and BICP. Similarly, Hermann et al. (2000) demonstrated in the same animal model a BICP value of −1.57 mm in the equicrestal group. Their implants underwent a triple loosening and retightening procedure of the healing abutment which may have led to the more pronounced 'dish-shaped' bone defect around the implants which can be seen on their histologies compared with our histologies. Todescan et al. (2002) found a BICP value of −2.28 mm in equicrestally placed implants in dogs. These implants were geometrically identical to our implants in the TIU group but did not have a rough surface. This may be a reason for the difference in BICP (−2.28 vs. −1.53 mm). In general, however, it seems that the first bone-to-implant contact in equicrestally placed implants with a smooth collar establishes itself at 1.5–2 mm apical to the microgap. Abrahamsson et al. (1999) demonstrated a BICP of −0.85 mm in another dog experiment (3 months submerged healing followed by 6 months of non-submerged maintenance) using implants with a rough surface all the way to the implant shoulder. Therefore, roughening of the implants to the level of the microgap may decrease the distance of implant shoulder to first bone-to-implant contact in equicrestally placed implants.

More pronounced differences were found in the horizontal parameters HBD and SLO. The periimplant bone approached the implant shoulder double as close in the ANK group as in the TIU group. The angle of the periimplant bone slope was half as big as in the ANK compared with the TIU group at a significance level of $P<0.05$. It seems that the implant connection type of the TIU group (non-conical butt joint with no horizontal offset) exerts a more laterally pronounced influence on the periimplant bone than the connection type of the ANK group (Morse taper connection with horizontal offset). Comparable studies in the past have not examined the horizontal/lateral effects of the microgap. Tarnow et al. (2000) radiographically assessed HBD in 36 patients 1–3 years after stage two surgery in implants similar to the TIU group implants. They found HBD values of −1.34 and −1.40 mm. These values are considerably higher than ours but represent a situation after several years of microbial contamination of the microgap and mechanical loading.

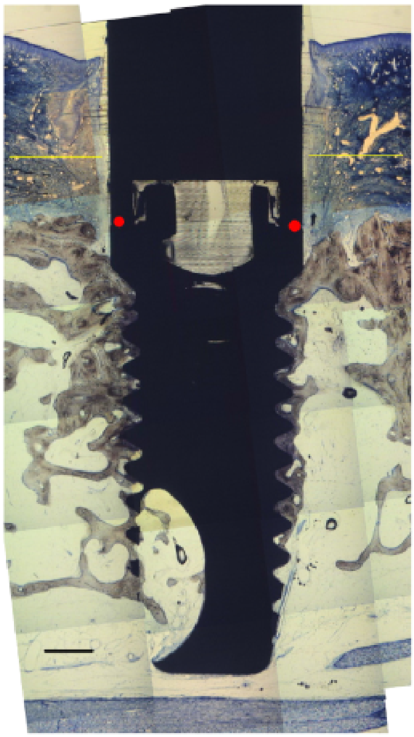

Fig. 11. Implant of the subcrestal TIU group. Note the amount of bone loss since implant insertion and the flat periimplant bone slope. The periimplant bone seems to avoid contact with the microgap. Red dots indicate microgap. Yellow line shows bone level at implant placement. Black bar represents 1 mm.

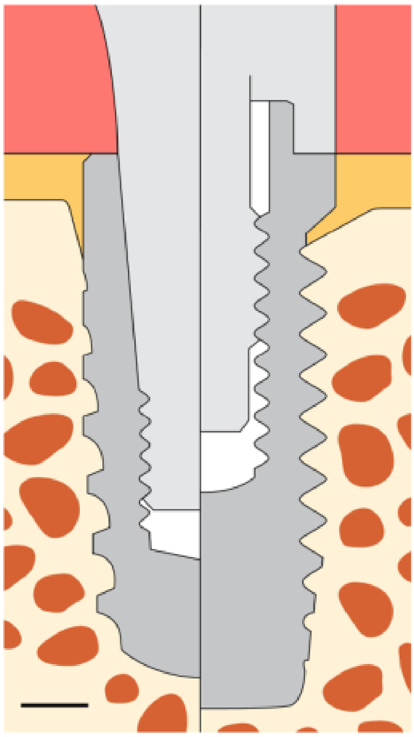

Fig. 12. Illustration of the bone morphology for the ANK group (left side) and the TIU group (right side) in the equicrestally placed implants. Drawing is based on the mean values of the three parameters PBL, BICP and HBD. The horizontal line separating the orange from the red area delineates the bone level at the time of implant placement. Bar represents 1 mm.

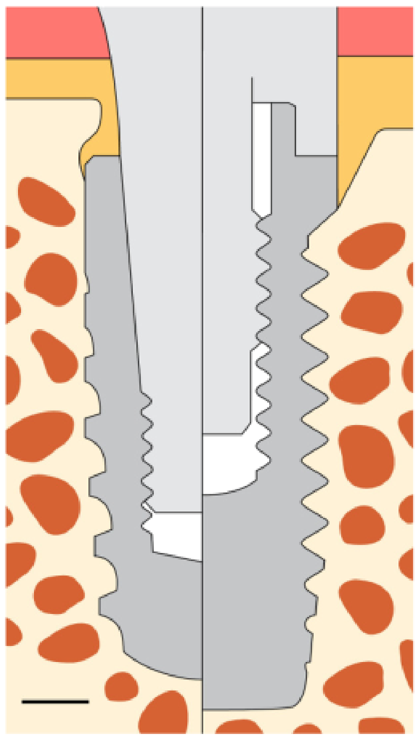

Fig. 13. Illustration of the bone morphology for the ANK group (left side) and the TIU group (right side) in the subcrestally placed implants. Drawing is based on the mean values of the three parameters PBL, BICP and HBD. The horizontal line separating the orange from the red area delineates the bone level at the time of implant placement. Bar represents 1 mm.

***Table 1*. Histometric measurements of the equicrestally placed implants (mean values ± standard deviations)**

$n=8$	PBL	BICP	HBD	SLO
ANK group	−0.69 ± 0.47 mm	−1.60 ± 0.97 mm	−0.23 ± 0.23 mm	35.36 ± 25.79°
TIU group	−0.91 ± 0.48 mm	−1.53 ± 0.43 mm	−0.51 ± 0.32 mm	63.22 ± 16.75°
P-value	>0.05	>0.05	>0.05	<0.05

n, number of animals.

***Table 2*. Histometric measurements of the subcrestally placed implants (mean values ± standard deviations)**

$n=8$	PBL	BICP	HBD	SLO
ANK group	0.90 ± 0.46 mm	−0.41 ± 0.72 mm	0.19 ± 0.23 mm	20.40 ± 11.61°
TIU group	0.42 ± 0.31 mm	−0.81 ± 0.27 mm	−0.57 ± 0.16 mm	44.43 ± 8.85°
P-value	>0.05	>0.05	<0.001	<0.001

n, number of animals.

When the implants were inserted in a 1.5 mm subcrestal position, the results for PBL and BICP were double as high in the ANK group compared with the TIU group (0.90 vs. 0.42 mm for PBL, and −0.41 vs. −0.81 mm for BICP), although statistical significance was not reached. Considering the fact that the implants were placed 1.5 mm below bone level a loss of 0.6 mm in the ANK group almost seems to equal the loss due to the surgical trauma of inserting an implant itself. Todescan et al. (2002) found a BICP value of −1.68 mm in implants placed 1 mm subcrestally. Again, the smooth surface may account for this finding. But also Hermann et al. (2000) reported a BICP value of −1.25 mm in implants placed 1 mm subcrestally with a small smooth collar and a butt joint connection without an offset. More pronounced differences at a significance level of $P<0.001$ between the ANK group and the TIU group were detected in the parameters HBD and SLO. The implants in the ANK group presented in almost all sections with bone growth onto the implant shoulder (mean 0.19 mm) whereas in the implants of the TIU group the periimplant bone seemed to keep the same horizontal distance from the microgap as in the equicrestally placed implants (−0.57 vs. −0.51 mm). This periimplant bone characteristics is reflected in the very narrow 'dish-shaped' defect of only 20.40° in the ANK group.

Another finding of this study is that the first bone-to-implant contact seems to establish itself significantly further coronally, if the implants are placed subcrestally instead of equicrestally. Also the periimplant bone slope becomes steeper in those cases (significant for TIU group only). Additionally it was found that in ANK implants bone growth onto the implant shoulder was found, if subcrestal placement was carried out. This was significantly different from the equicrestally placed implants. The observation that bone was maintained on the smooth collar part of the ANK implants might indicate that differences in the implant-abutment connection type (i.e. less micromovement and less bacterial contamination) have a more pronounced influence on the bone-to-implant contact than the roughness of the surface *per se*. However, the higher standard deviations for BICP in the ANK groups point to a higher variability with regard to the actual BICP.

The fact that periimplant bone was able to grow over the microgap only in the Morse taper connection-type implants may mean that either microbial contamination or micromechanical movement or the combination thereof is reduced in such implants. The reduced micromovement has been demonstrated by Zipprich et al. (2004, 2005a, 2005b, 2007). Histological contact with the healing abutment (as seen in the ANK groups) will, of course, disappear after several abutment changes as performed in the study by Hermann et al. (1997, 2000). Nevertheless, it is noteworthy that even in their type C, D and F implants radiological bone contact to the microgap had already been lost in the very first radiograph (at 4 weeks) after abutment connection (to a level of ca. 2 mm apical to the microgap), before the first loosening of healing abutments was performed. To our knowledge the present study is the first to demonstrate histological contact between living bone tissue and a microgap respectively a healing abutment 3 months after stage two surgery.

Within the limits of an animal study it can be concluded that 3 months after uncovering a submerged implant (1) a resorption of the original periimplant bone height of 0.5–1 mm can be expected, (2) the first bone-to-implant contact is located closer to the implant shoulder if the implant was placed 1.5 mm subcrestally compared with an equicrestal insertion and (3) the 'dish-shaped' defect configuration is more pronounced in a non-conical butt joint connection without horizontal offset. Clinical implications of these findings might be that the extension of a 'dish-shaped' periimplant bone defect is dependent on the implant-abutment connection, especially if an implant is inserted in a subcrestal position, and that narrowing the 'funnel' of such defects might allow for better soft tissue support.

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