Influence of Microgap Location and Configuration on Radiographic Bone Loss in Nonsubmerged Implants: An Experimental Study in Dogs

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Purpose: The implant-abutment connection (microgap) influences the peri-implant bone morphology. However, it is unclear if different microgap configurations additionally modify bone reactions. This preliminary study aimed to radiographically monitor peri-implant bone levels in two different microgap configurations during 3 months of nonsubmerged healing. ***Materials and Methods:*** Six dogs received two implants with internal Morse taper connection (INT group) on one side of the mandible and two implants with external-hex connection (EXT group) on the other side. One implant on each side was positioned at bone level (equicrestal); the second implant was inserted 1.5 mm below the bone crest (subcrestal). Healing abutments were attached directly after implant insertion, and the implants were maintained for 3 months without prosthetic loading. At implant placement and 1, 2, and 3 months, standardized radiographs were taken to monitor peri-implant bone levels. ***Results:*** All implants osseointegrated. A total bone loss of 0.48 ± 0.66 mm was measured in the equicrestal INT group, 0.69 ± 0.43 mm in the equicrestal EXT group, 0.79 ± 0.93 mm in the subcrestal INT group, and 1.56 ± 0.53 mm in the subcrestal EXT group ($P > .05$, paired t tests). Within the four groups, bone loss over time became significantly greater in the EXT groups than in the INT groups. The greatest bone loss was noted in the subcrestal EXT group. ***Conclusion:*** Within the limits of this animal study, it seems that even without prosthetic loading, different microgap configurations exhibit different patterns of bone loss during nonsubmerged healing. Subcrestal positioning of an external butt joint microgap may lead to faster radiographic bone loss. *Int J Prosthodont 2011;24:445–452.*

Dental implants as a therapeutic means to treat edentulism have gained increasing popularity because of high predictability.[1] Thus, various new parameters have been investigated to determine their impact on the outcome of implant therapy.[2–5] One of the main research foci has been the mechanism of how the implant and prosthetic abutment are connected to one another.[6] A general trend can be observed toward an internal connection design where the male part is located in the abutment and the female part is hosted in the implant. Despite the predominance of internal connection types, it can be observed that there is a wide range of respective connections in terms of tightness and rigidity. This, in turn, results in differing amounts of microbial leakage[7,8] and in varying degrees of mechanical stability.[9,10] As a consequence, the soft and hard tissues surrounding the implant may present distinct reactions to the type of implant-abutment connection.[11]

The border line between the implant and abutment has been termed the "microgap." Human and animal radiographic studies of flush (butt joint) implant-abutment connection types showed that the first detectable bone-to-implant contact keeps a vertical distance of 1.5 to 2.0 mm from the microgap, irrespective of whether the microgap level was located above, at, or below the bone crest at stage-one surgery.[12–22] This initial loss of peri-implant hard tissue usually occurs before the first year of loading is complete, which is why it has been ascribed to a bone modeling and remodeling process subsequent to second-stage surgery and to the early phases of

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prosthetic loading. Since this initial bone loss seemed to be unavoidable, it has been included in the scientific criteria for how implant success is defined.[23,24] This peri-implant bone resorption has become apparent in radiographic investigations as a dish-shaped defect (saucerization) around the microgap and has been termed "peri-implant bone remodeling down to the first implant thread."

If viewed from a perspective of mere implant function, this early loss of peri-implant hard tissue may not be crucial for the long-term survival of the implant. However, in sites of esthetic concern, any bone loss may be accompanied by soft tissue shrinkage.

The scope of this investigation was to radiographically monitor the peri-implant bone levels in two different implant-abutment connection (microgap) types with different vertical microgap locations in relation to the bone crest over 3 months of nonsubmerged, unloaded healing in dogs.

Materials and Methods

The Ethical Committee for Animal Investigations of the Dental School of Araçatuba, UNESP-Universidade Estadual Paulista, Araçatuba, Brazil, approved the study protocol of this animal experiment. General anesthesia with atropine sulphate, xylazine, and tiletamine/zolazepam was used to perform the surgeries and radiographic examinations. To reduce hemorrhage, lidocaine with epinephrine was applied as a local anesthetic agent. In addition, antibiotics (espiramizine/metronidazol) and nonsteroidal anti-inflammatory drugs (flunixine/meglumine) were administered perioperatively. During the first weeks after implant insertion, intraoral chlorhexidine digluconate rinses were used as an anti-infective agent three times per week.

To determine the sample size of this study, the following calculations and assumptions were made: both the mean difference in radiographic bone height to be detected and the expected standard deviations were set at 0.5 mm at a significance level of .05 and a power of 80%.

Surgery

Six mongrel dogs were used in this animal study. To create an edentulous area, all mandibular premolars and the first mandibular molar were extracted carefully on both sides. The extraction sites did not receive further treatment and were given a healing period of 3 months. Then, a crestal incision was made, and full-thickness flaps were elevated to the buccal and lingual aspects on either side of the mandible. Round burs in a low-speed hand piece were used to create a flat crestal surface with a buccolingual width of 6 to 7 mm. According to the manufacturers' guidelines, two implant osteotomies were drilled with copious saline irrigation on each side of the mandible. Two endosseous dental implants with a grit-blasted surface and an internal Morse taper connection (3.5-mm diameter, 8-mm length; Ankylos A8, Dentsply Friadent; INT group) were placed in one side. The implant shoulder of one of the implants was vertically aligned at the level of the surrounding bone crest (equicrestal position), whereas the implant shoulder of the other implant was vertically oriented 1.5 mm below the bone crest (subcrestal position). On the other side of the mandible, the same vertical alignments were made (equicrestal and subcrestal) but a different implant type was used, namely a screw-type implant with an oxidized surface and an external-hex connection (3.75-mm diameter, 8.5-mm length; TiUnite Brånemark, Nobel Biocare; EXT group). In the six animals, the two different implant systems were alternatively inserted in the left or the right side. With regard to the subcrestal and equicrestal alignment, anterior and posterior positions were alternated as well. However, only one implant system was placed on a given mandibular side, and the vertical position of the implant shoulders was the same on both sides. Directly after implant insertion, healing abutments were attached to the implants and tightened manually. Their vertical height was selected subject to the vertical position of the implant shoulder in the bone to obtain a comparable height of intraorally exposed metal for all implants (approximately 3 to 4 mm). Thereafter, the mucoperiosteal flaps were readapted around the healing abutments and kept in position with single interrupted sutures.

Implants were allowed a nonsubmerged healing period of 3 months. Removal of the sutures was done 1 week postoperatively. Rinses with 0.2% chlorhexidine digluconate were applied three times per week for the first 2 weeks, and only once per week thereafter.

Radiology

Four radiographs were taken for each of the implants: the first after the sutures were completed at the end of stage-one surgery and three more at 1, 2, and 3 months after implant insertion. For standardization and reproduction purposes, a stent was made from a silicone putty material (Provil, Heraeus Kulzer) for the first radiograph and reused for subsequent radiographs. The stent was rigidly connected to a plastic film holder, which itself was attached to a ring on the radiographic tube via metal bars. The settings for the radiographs were 65 kV, 7.5 mA, and 0.12 seconds.

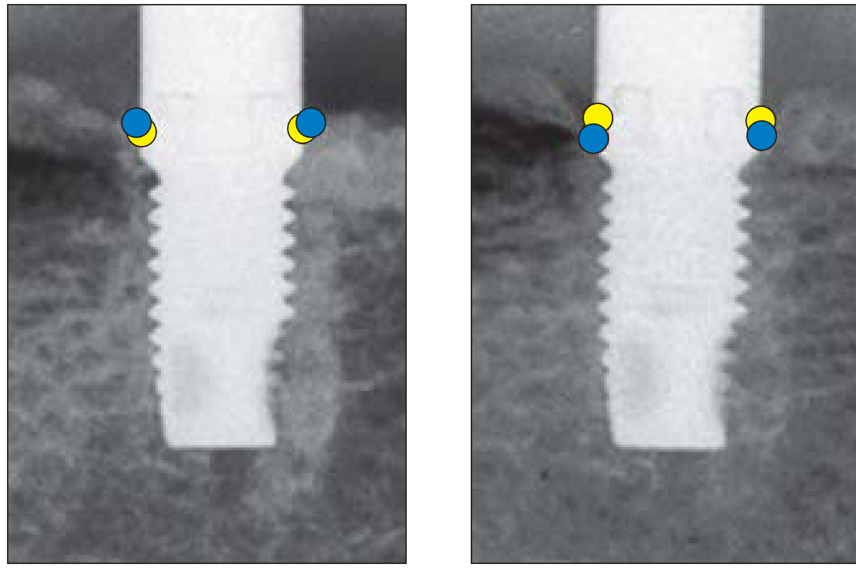

Fig 1 Radiograph from the equicrestal EXT group *(left)* immediately after implant insertion and suturing and *(right)* 3 months later. Yellow dots = microgap; blue dots = radiographically detected bone-to-implant contact point.

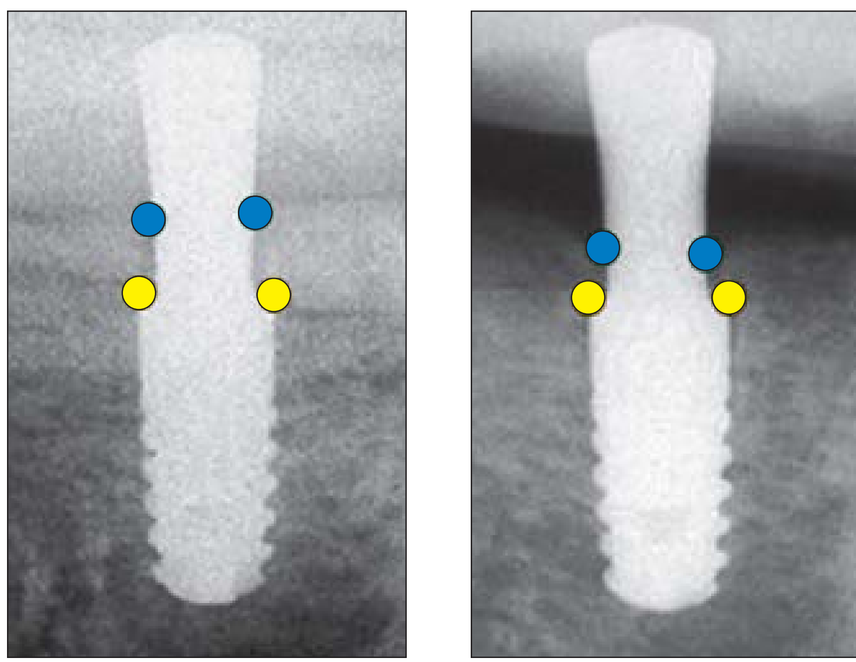

Fig 2 Radiograph from the subcrestal INT group *(left)* immediately after implant placement and *(right)* 3 months later. Yellow dots = microgap; blue dots = radiographically detected bone-to-implant contact point.

The conventional radiographs were digitally scanned, and both contrast and brightness were enhanced to optimize evaluation with the imaging software (Imagelab 2000, Diracon Bio Informática). The most coronal, radiologically detectable contact point between bone and implant was identified on both the mesial and distal side of each implant. The vertical distance between this contact point and the horizontal level of the implant shoulder was assessed digitally in millimeters. The measurement was given a positive value if the first bone-to-implant contact was found coronal to the implant shoulder level (Figs 1 and 2).

Statistical Analysis

A preliminary comparison of the mesial values with their corresponding distal measurements in all available radiographs showed no significant difference between the mesial and distal aspects. Therefore, the mesial and distal measurements of each radiograph were averaged to one mean per radiograph. Thus, the statistical unit was the implant (equal to the animal). To compare the two implant systems at the same insertion depth (equicrestal or subcrestal) and the same time point (0, 1, 2, or 3 months),

Table 1 Distance from the First Radiographic Bone-to-Implant Contact (Mean ± Standard Deviation) to the Implant Shoulder of Equicrestally Placed Implants*

	Time (mo)				
	0	1	2	3	Total bone loss
INT group (n = 6)	0.25 ± 0.26	0.01 ± 0.81	–0.11 ± 0.87	–0.24 ± 0.87	0.48 ± 0.66
EXT group (n = 6)	0.16 ± 0.44	–0.01 ± 0.59	–0.43 ± 0.67	–0.53 ± 0.79	0.69 ± 0.43
P	> .05	> .05	> .05	> .05	> .05

*Positive numbers reflect a bone level crestal to the implant shoulder.

Table 2 Distance from the First Radiographic Bone-to-Implant Contact (Mean ± Standard Deviation) to the Implant Shoulder of Subcrestally Placed Implants*

	Time (mo)				
	0	1	2	3	Total bone loss
INT group (n = 6)	2.13 ± 0.10	1.89 ± 0.74	1.62 ± 0.87	1.34 ± 0.99	0.79 ± 0.93
EXT group (n = 6)	1.31 ± 0.29	0.49 ± 1.10	0.06 ± 0.90	–0.25 ± 0.77	1.56 ± 0.53
P	< .01	> .05	> .05	< .05	> .05

*Positive numbers reflect a bone level crestal to the implant shoulder.

paired *t* tests were used. For the comparison of the equicrestal and subcrestal groups within the same implant system during the different time points of the study, repeated-measures analysis of variance tests were applied. Thereafter, the Bonferroni correction was used to detect the respective group differences. The level of significance was set at .05.

Results

Clinical and Gross Radiographic Results

Wound healing was uneventful and without postoperative complications or adverse events during the nonsubmerged healing phase. During the radiographic controls and at the end of the study, all implants were stable clinically. The overview observation of the radiographs did not reveal any implant failure. The radiographs did not show excessive radiologic bone loss or signs of periapical radiolucencies. Both implant groups in both vertical insertion position groups revealed some radiologic bone loss during the nonsubmerged healing phase. This bone loss was slightly higher in the subcrestal groups and most pronounced in the subcrestal EXT group. The clinical appearance of the peri-implant mucosa seemed healthy, with occasional signs of slight inflammation.

Radiologic Measurements

Table 1 summarizes the means, standard deviations, and *P* values of the radiologic assessments for the equicrestally placed implants; Table 2 summarizes these values for the subcrestally placed implants. Figures 3a and 3b depict these changes graphically over the duration of the study. When the bone loss within the same implant system and the same vertical position group was compared to baseline radiographs, significant differences were noted in the EXT group earlier than in the INT group. Direct comparison between the INT and EXT groups revealed a significant difference in the submerged group at 3 months only, although a tendency toward better bone maintenance was visible in the equicrestal group.

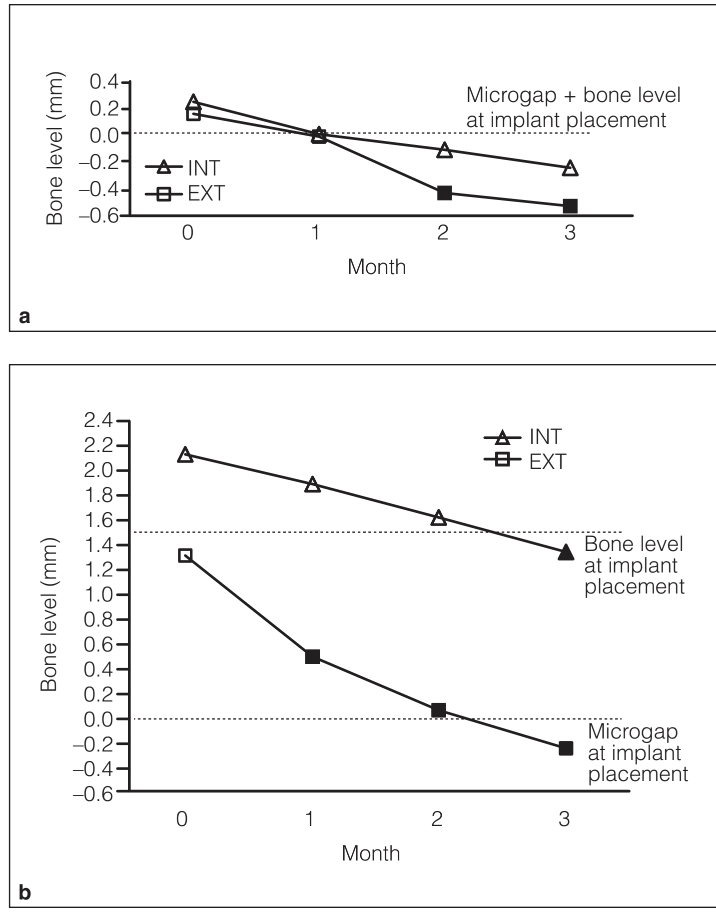

Fig 3 Radiographic bone level data in the **(a)** equicrestal group and **(b)** subcrestal group in mm from month 0 to 3. Filled symbols denote a significant difference ($P < .05$, repeated-measures analysis of variance) between that specific point in time compared to the baseline bone measurement at the day of implant insertion.

Discussion

Radiographic studies in animals certainly rank lower in evidence level when compared to radiographic investigations in humans. Nevertheless, the canine model is well documented in the scientific literature to monitor radiologic changes,[19,25,26] since it allows for more frequent radiographs than in human studies. Clinically normal implants would not have to undergo this amount of unnecessary exposure to radiation. Because of a sufficient buccolingual mandibular width in the mongrel dog, an identical implant diameter could be used as in humans. To avoid influence of the sagittal position of the implant within the mandible, a statistical comparison was run between implants placed in the anterior position and implants in the posterior position. However, no difference was detected. In this experiment, methods were applied that were similar to a comparable setting in a human study monitoring radiographic bone levels: Stents, which were fabricated directly in the mouth, were used to produce radiographs from the same direction,[19,27,28] and digital subtraction radiography[29–31] was deliberately avoided, since this method is rather complicated to implement in a clinical study in humans. Instead, it was agreed to digitally scan the radiographs and to enhance contrast and brightness to allow for optimal evaluation, as might be done with a radiograph in a clinical environment.

No prosthetic loading was allowed for the implants in this study, nor did they undergo any changes of the healing abutments, as becomes necessary when an impression is taken, during framework and color try-out, or when prostheses are inserted. This was done on purpose because the sheer exposure of the microgap to the oral environment and the subsequent influence on peri-implant bone was the subject of the study, rather than further effects attributable to the stability of the implant-abutment connection (as in prosthetic loading) or the cleanliness of abutment changes (as in repeated screw loosening and tightening).[32,33] However, there was still a certain amount of loading present resulting from lip and tongue pressure. Also, chewing on cage bars or drinking outlets was not prevented by muzzles, but a soft diet was deemed adequate to minimize loading.

In general, the differences between the equicrestal INT and EXT groups were not pronounced. Both equicrestal groups exhibited a certain amount of bone loss. During the healing period of 3 months, the bone loss amounted to 0.48 mm in the INT group compared to 0.69 mm in the EXT group (see Table 1). Whereas the total bone loss in the equicrestal EXT group became significant 2 months after stage-one surgery compared to the baseline radiograph, the bone loss in the equicrestal INT group was not significant during the observation period of 3 months. A loss of 0.48 mm, as seen in the equicrestal INT group, might be attributable to the general trauma of stage-one surgery. Considering the fact that in nonsubmerged healing the stability or contamination of the implant-abutment connection might exert an influence on peri-implant bone resorption, an overall bone loss of approximately 0.5 mm can be considered minimal. In a similar experiment, equicrestally placed implants that underwent a submerged healing period of 3 months followed by a nonsubmerged healing period of another 3 months did not show higher radiographic bone resorption rates, at least not in the INT group.[34] This is in accordance with a dog study of Abrahamsson et al,[35] who did not find any differences between the radiographic bone loss in submerged and nonsubmerged implants with a Morse cone implant-abutment connection when the implants were inserted equicrestally (0.33 vs 0.20 mm). Fiorellini et al[36] performed a dog study in which they compared submerged and nonsubmerged healing in implants of an internal implant-abutment connection (without a Morse cone). Radiographic differences in bone loss were not detected after 18 weeks. However, the groups used in that study had not been exposed to the oral environment for equal time periods (18 weeks for nonsubmerged healing implants and 6 weeks for the submerged ones). Just as in the current study, bone resorption was most pronounced directly after the first contact with the oral environment and reached a steady state thereafter.

Different results were found in the subcrestally placed groups. During the nonsubmerged healing of 3 months, the radiographic bone loss added up to 0.79 mm in the subcrestal INT group and 1.56 mm in the subcrestal EXT group (see Table 2). When compared to the baseline radiographs, this bone loss did not become significant until the third month in the INT group, but was significant after the first month in the EXT group (see Fig 3b). The higher surgical trauma associated with subcrestal implant placement may account for the more pronounced bone loss compared to the equicrestal groups. Interestingly enough, the bone loss of 0.79 mm in the subcrestal INT group after nonsubmerged healing of 3 months matches the total bone loss of 0.76 mm for the subcrestal INT group in a similar experiment after submerged healing of 3 months followed by nonsubmerged healing for another 3 months.[34] Therefore, it may be concluded that there is no difference in radiographic bone loss between implants of the INT group that have undergone either nonsubmerged or submerged healing as long as they have been inserted in a subcrestal position. There was a slightly higher bone loss in the nonsubmerged subcrestal EXT group (1.88 mm) compared to the submerged subcrestal EXT group (1.56 mm).[34] Interestingly enough, the final radiographic bone height in the subcrestal groups was markedly coronal to the microgap in the INT group (1.34 mm), whereas it was apical to the microgap in the EXT group (–0.25 mm) (Fig 3b). Other factors than the connection type (eg, macrodesign and surface roughness) may have contributed to these results. However, both treatment groups exhibited a machined collar height of 0.75 mm (EXT group) and 1.3 mm (INT group), the first implant thread was found at a distance of 1.2 mm (EXT group) and 1.75 mm (INT group) from the implant shoulder, and the microroughness amounted to 1.1 μm (EXT group) and 12.8 μm (INT group).[37,38] These factors, especially the first two, would seem to favor the EXT group to allow for more coronally located bone heights than the INT group. The contrary was found, however, which might bring up the question of whether higher micromovement and subsequent bacterial colonization of the microgap as direct consequences of a reduced stability of the implant-abutment connection[39] in the EXT group might possibly overrule the benefits of macro- and microdesign and keep the first bone-to-implant contact at a certain distance from the implant-abutment connection.

Hermann et al,[40] in another dog study, examined the distance between the microgap and first radiographic bone contact during a total healing period of 6 months. Their group C corresponded to equicrestal placement with nonsubmerged healing. After 3 months, they reported a bone loss of approximately 1.7 mm. The bone level at this time was approximately 1.9 mm coronal to the microgap. In the current study, the bone loss in the equicrestal groups was 0.48 mm (INT) and 0.69 mm (EXT), with corresponding bone heights of 0.24 and 0.53 mm apical to the microgap, respectively. From this comparison, it seems that the configuration of the implant-abutment connection and the surgical trauma to seat a certain implant system in the bone exert a bigger influence on the radiographic bone height and maintenance than thought previously. It is unquestioned that frequent changes of implant abutments, as performed in the study of Hermann et al[40] for the simulation of prosthetic procedures, will contribute to additional bone loss. Despite the fact that such changes were not performed in the current study, it is noteworthy that in the nonsubmerged treatment group C of the Hermann et al[40] study, a radiographic bone loss of approximately 2 mm was visible 4 weeks after implant insertion, ie, before the simulation of prosthetic procedures via loosening and retightening of the healing abutments.

Conclusions

Within the limits of this animal study, the following can be concluded:

- Irrespective of the vertical position of the implant-abutment connection in relation to the peri-implant bone level at implant placement, radiographic bone loss will occur in nonsubmerged healing implants.
- This bone loss can become significant compared to the baseline bone height as soon as 1 month after implant placement.
- An external butt joint microgap configuration may lead to more pronounced bone loss during the initial healing phase than an internal Morse cone connection, especially if the implant-abutment interface is positioned subcrestally.

As previously described, contamination of the microgap with microorganisms or micromechanical instability of the implant-abutment connection might be possible explanations for these observations.[7,10,26,37]

Acknowledgments

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Literature Abstract

Role of pathogenic oral flora in postoperative pneumonia following brain surgery

This study investigated the importance of assessing periodontal status before neurosurgical procedures in older patients to identify those at high risk for developing postoperative pneumonia. The prophylactic effects of a single dose of preoperative cefazolin on oral bacteria were also investigated. A matched cohort of patients (n = 18) without postoperative lung complications was compared to patients who developed pneumonia within 48 hours after brain surgery (n = 5). Patients admitted for elective operation of a single brain tumor underwent dental examination and saliva collection before surgery. Bacteria from saliva cultures were isolated, and periodontal disease was scored according to type and severity. Patients received 15 mg/kg cefazolin intravenously at the start of surgery. The results showed that the number and severity of coexisting periodontal diseases were significantly greater in patients with postoperative pneumonia in comparison to the control group ($P = .031$ and $P = .002$, respectively). The relative risk of developing postoperative pneumonia in high–periodontal score patients was 3.5 times greater than that in patients who had a low periodontal score ($P < .0001$). Cefazolin concentration in saliva and bronchial secretion remained below detectable levels in every patient. The authors concluded that the presence of multiple periodontal diseases and pathogenic bacteria in the saliva are important predisposing factors for postoperative aspiration pneumonia in patients after brain surgery. The authors suggested that dental examination may be justifiable to identify patients who are at a high risk of developing postoperative respiratory infections.

Bágyi K, Haczku A, Márton I, et al. *BMC Infect Dis* 2009;9:104. **References:** 65. **Reprints:** Dr Almos Klekner, Department of Neurosurgery, Medical and Health Science Center, University of Debrecen, Debrecen, Hungary—*Sapphire T. Gan, Singapore*