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Bone level change at implant-supported fixed partial dentures with and without cantilever extension after 5 years in function

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Abstract

Objective: The aim of this study was to retrospectively analyze whether the inclusion of cantilever extensions increased the amount of marginal bone loss at free-standing, implant-supported, fixed partial dentures (FPDs) over a 5-year period of functional loading.

Material and Methods: The patient material comprised 45 periodontally treated, partially dentate patients with a total of 50 free-standing FPDs supported by implants of the Astra Tech® System. Following FPD placement (baseline) the patients were enrolled in an individually designed supportive care program. A set of criteria was collected at baseline to characterize the FPDs. The primary outcome variable was change in peri-implant bone level from the time of FPD placement to the 5-year follow-up examination. The comparison between FPDs with and without cantilevers was performed at three levels: FPD level, implant level, and surface level. Bivariate analysis was performed by the use of the Mann–Whitney *U*-test and stepwise regression analysis was utilized to evaluate the potential influence of confounding factors on the change in peri-implant bone level.

Results: The overall mean marginal bone loss for the implant-supported FPDs after 5 years in function was 0.4 mm (SD, 0.76). The bone level change at FPDs placed in the maxilla was significantly greater than that for FPDs in the mandible (0.6 versus 0.2 mm; $p < 0.05$). No statistically significant differences were found with regard to peri-implant bone level change over the 5 years between FPDs with and without cantilevers at any of the levels of comparisons. The multivariate analysis revealed that the variables jaw of treatment and smoking had a significant influence on peri-implant bone level change on the FPD level, but not on the implant or surface levels. The model explained only 10% of the observed variance in the bone level change.

Conclusion: The study failed to demonstrate that the presence of cantilever extensions in an FPD had an effect on peri-implant bone loss.

Key words: bone loss; cantilever units; fixed partial dentures; implants

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The incorporation of cantilever extensions in implant-supported fixed partial dentures (FPDs) may result in unfavorable loading conditions and the occurrence of undue stress concentrations at the implant sites (Rangert 1995). This may cause damage to the endosseous implant as well as to the surrounding tissues and, hence, compromise the long-term prognosis of the rehabilitation.

Findings from in vitro studies revealed that higher stress concentrations developed at implants that supported cantilever units than at implants without such elements (White et al. 1994, Sertgöz & Guvener 1996, Arataki et al. 1998, Barbier & Schepers 1998, Stegaroiu et al. 1998, Akça & Iplikçioglu 2002). It was further observed that the enhanced stress (i) occurred mainly at the bone crest adjacent to the distal surface of the implant that was facing the cantilever extension and (ii) was dependent on the length of the cantilever segment. Barbier & Schepers (1997) reported from an animal study that the presence of cantilevers in an FPD might stimulate bone remodeling and result in an increased density of the trabecular bone and a thickening of the cortical layer of the adjacent ridge. The authors also described, however, the presence of inflammatory lesions and enhanced numbers of osteoclasts in the tissues surrounding the implant closest to the cantilever unit. Barbier & Schepers (1997) speculated that such lesions might have resulted in marginal bone loss if the experiment had been extended over longer time intervals.

The hypothesis that excessive, non-axial load inflicted on an implant-supported FPD may have a detrimental effect on the peri-implant bone was to some extent supported by data from experimental studies in the monkey by Isidor et al. (1996, 1997). It was reported that while biofilms present on the implant surface caused overt soft tissue inflammation and marginal bone loss, overload induced by non-axial, interrupted forces resulted in loss of osseointegration, rather than reduction in the height of marginal bone. The finding that excessive load may not cause marked loss of marginal bone height was corroborated by findings in a series of dog experiments by Gotfredsen et al. (2001a, b). They exposed implants to laterally directed static load for periods extending from 10 to 46 weeks, and concluded that the bone tissue immediately adjacent to the implant retained its vertical dimension but exhibited a greater density than bone next to unloaded implants.

Observations made in studies in humans suggested that a relationship exists between excessive loading and peri-implant bone loss (Lindquist et al. 1988, Ahlqvist et al. 1990, Sanz et al. 1991, Quirynen et al. 1992, Rangert et al. 1995). It was also documented that the inclusion of cantilever extensions in an FPD caused an increase in the axial loading (Falk et al. 1989, Gunne et al. 1997). Medium- to long-term clinical trials designed to determine the potential influence of cantilever extensions on peri-implant bone stability are, however, few. Naert et al. (1992) reported data derived from examinations of 103 complete FPDs in 91 patients. The authors concluded that during a 3-year follow-up period the length of cantilever extension did not have a significant influence on the rate of marginal bone loss around the supporting implants. Lindquist et al. (1988), also evaluating implant-supported full-arch FPDs, found in a 6-year study that the length of cantilever extension significantly enhanced the amount of peri-implant bone loss at anterior but not at posterior implants next to the cantilever extension. The latter finding was further substantiated in a subsequent report of the 15-year follow-up data of the same patient sample (Lindquist et al. 1996). Although the clinical studies referred to indicated that cantilever extensions might not jeopardize the stability of the peri-implant bone level in a full-arch FPD, it is not properly documented whether in an FPD, supported by few implants, the load exerted on the cantilever extension may cause undue bone loss (Akça & Iplikçioglu 2002). In fact, in a recent publication of a clinical study by Romeo et al. (2003) it was reported that, after an average of 3 years in function, the amount of bone loss that had occurred at the implant closest to the cantilever extension in FPDs was correlated to the extension of the cantilever segment.

The aim of the present study was to retrospectively analyse whether the inclusion of distal cantilever extensions increased the amount of marginal bone loss that took place at free-standing, implant-supported FPDs over a 5-year period of functional loading.

Material and Methods

The original sample included 51 partially dentate patients with a total of 56 free-standing FPDs supported by Astra implants (Astra Tech® Dental Implant System, Mölndal, Sweden) who were participants in a longitudinal prospective study (Wennström et al. 2004). The patients, who exhibited advanced chronic periodontitis, had received comprehensive periodontal treatment of the remaining dentition before the implant placement, and were, after completion of the restorative therapy, maintained on an individually designed supportive care program.

Six FPDs did not meet the inclusion criteria for the present study that included 5 years of follow-up; three FPDs belonged to patients who were lost to the follow-up examination and three FPDs had experienced implant failure. All three implant failures occurred in 3 U FPDs supported by two implants, out of which two FPDs had been designed with cantilever units (for details see Wennström et al. 2004). Hence, a total of 50 FPDs in 45 patients were available for the present analysis, 24 FPDs with and 26 FPDs without cantilever extensions.

Prior to implant installation, panoramic radiographs were obtained from each patient. The height of the periodontal bone (PBL) present at all remaining teeth was assessed according to the method described by Björn et al. (1969) and by an examiner not otherwise involved in the clinical trial. The mean PBL value (%) was calculated for each patient.

The surgical treatment was performed by two periodontitis, and according to the manufacturer's manual (for details see Wennström et al. 2004). All implants used had a diameter of 3.5 mm while the length varied between 8 and 19 mm. Each patient received a minimum of two implants. Abutment connection was performed in a second stage surgical procedure 3 months (mandible) or 6 months (maxilla) after implant installation. Standard, Uni-abutments® (Astra Tech® Dental Implant System) of varying length were used.

The prosthetic treatment was performed by prosthodontists and followed the manual provided by the manufacturer. The final, screw-retained FPD was completed and delivered about 4 weeks after abutment connection. In conjunction with the installation of the FPDs, the patients were given additional oral hygiene instruction with special emphasis on how the implants must be cleaned.

Patient characteristics

The mean age of the subjects (Table 1) varied between 57 years (group C; FPDs with cantilever units) and 62 years (group NC; FPDs without cantilevers). In group C, there were eight males and 16 females while in NC the corresponding numbers were nine and 14, respectively. In both groups the majority of the patients were non-smokers; 14 in group C and 18 in group NC. They had on the average 18.5 (C) and 18.3 (NC) remaining teeth, the mean PBL of which varied between 42.7% (C) and 45.1% (NC).

FPD characteristics

For description of the FPD characteristics, the following variables were recorded:

Table 1. Characteristics of the patient sample

	Cantilever FPDs	Non-cantilever FPDs
no. of patients/FPDs	24/24	23/26
age	57 (10.3)	62 (8.5)
gender (male/female)	8/16	9/14
smokers/non-smokers	10/14	5/18
Remaining natural dentition		
no. of teeth	18.5 (4.3)	18.3 (4.4)
mean bone level	42.7 (7.2)	45.1 (7.1)

Mean values and standard deviations.
FPD, fixed partial denture.

Table 2. Characteristics of the implant-supported FPDs

	Cantilever FPDs	Non-cantilever FPDs
jaw (maxilla/mandible)	16/8	12/14
FPD length (mm)	28.9 (8.8)	23.4 (3.1)
no. of crown units	4.0 (1.3)	3.0 (0.3)
no. of implants	2.6 (0.7)	2.8 (0.4)
ratio crown units/implants	1.6 (0.2)	1.1 (0.2)
mean implant length (mm)	12.7 (1.8)	12.7 (2.0)
mean abutment/crown height (mm)	13.8 (3.8)	11.4 (2.6)
cantilever extension (mm)	9.0 (1.6)	–

Mean values and standard deviations.
FPD, fixed partial denture.

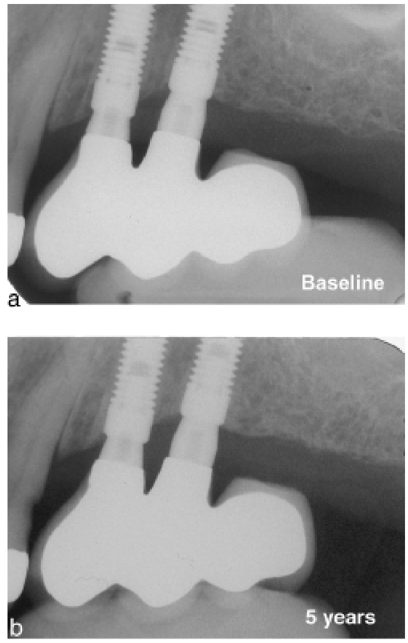

Fig. 1. Radiographs illustrating the design of cantilever fixed partial dentures. (a) Baseline and (b) 5-year follow-up.

- Jaw of placement.
- Number and length of supporting implants.
- Number of crown units and material used in the occlusal surface.
- Type of occluding antagonist (natural tooth, tooth supported FPD, implant-supported FPD or missing).
- Height of crown/abutment unit; measured from the fixture/abutment level to the highest occlusal point of the prosthesis. The measurements were made with a sliding caliper to the nearest 0.5 mm and were performed at each of the implants that supported the FPD.
- Length of the cantilever extension (mesial–distal) was measured with a sliding caliper to the nearest 0.5 mm.

Twenty-four FPDs designed with cantilever units (group C) and 26 without such units (group NC) were available for the present analysis (Table 2). In group C, 16 FPDs were placed in the maxilla and eight in the mandible, while in group NC the corresponding numbers were 12 and 14. The mean number of implants used per FPD was 2.6 (SD, 0.7) in group C and 2.8 (0.4) in group NC and the mean length of the implants was in both groups 12.7 mm. The number of crowns used per FPD was 4.0 (group C) and 3.0 (group NC), while the corresponding numbers of crowns per implant were 1.6 and 1.1. The mean length (mesio-distal) of the FPDs was 28.9 mm (8.8) in group C and 23.4 mm (3.1) in group NC. The cantilever units were on the average 9.0 mm (1.6) long (Fig. 1). The mean height of the crown/abutment unit was 13.8 mm (3.8) in group C and 11.4 mm (2.6) in group NC.

In all FPDs, the occlusal surfaces were fabricated in porcelain and all but one FPD had natural teeth as antagonists, either alone or as part of tooth-supported prosthesis. Three of the FPDs were lacking occlusal contact in the cantilever segment of the prosthesis.

Radiographic examination

Radiographs of all implant sites, obtained by the use of a standardized parallel long-cone technique and custom-made stents, were taken at the time of insertion of the FPDs and at the 5-year follow-up examination. In the radiographs, the location of the marginal bone level – in relation to the marginal edge of the fixture – was assessed by the use of a magnifying lens (× 7) to the nearest 0.1 mm at the mesial and distal aspects of each implant. Two radiologists who were unaware of the purpose of the study performed all bone level assessments. The error of the radiographic assessment was determined through double recordings at one randomly selected implant from each patient representing the 5-year follow-up examination. The mean difference between the two readings was 0.04 mm (SD, 0.33).

Data analysis

The primary outcome variable was the change in peri-implant bone level from the time of FPD placement to the 5-year follow-up examination. The comparison between groups C and NC regarding this longitudinal bone level change was performed at three levels based on the subject as the statistical unit:

(i) FPD level: included data from all implants supporting the FPD.
(ii) Implant level: included data from the implant next to the cantilever unit (group C), or the most posterior implant (group NC).
(iii) Surface level: included data from the distal surface of the implant next to the cantilever unit (group C) or the most posterior implant (group NC).

For description of the data, mean values, standard deviations, and cumulative frequencies were calculated. Bivariate analysis was performed by the use of the Mann–Whitney *U*-test.

Stepwise regression analysis was utilized to evaluate the potential influence of various confounding factors on the observed longitudinal peri-implant bone level change. In the backward regression analyses both patient characteristics (age, gender, smoking habits, number of teeth, and PBL%) and FPD characteristics (jaw of placement, number of supporting implants, length of implants, height of the supra-construction, number of crown units, and length of cantilever extension) were included as independent variables. In all analyses a p-value of <0.05 was considered as being statistically significant.

Results

The overall mean reduction of the peri-implant bone level that occurred during the 5 years of observation for the implant-supported FPDs was 0.4 mm (SD, 0.76). For FPDs placed in the maxilla the mean loss of peri-implant bone amounted to 0.6 mm (0.84) compared with 0.2 mm (0.59) for FPDs in the mandible ($p<0.05$).

The mean longitudinal bone loss that had occurred at all implants (FPD level) in groups C and NC after 5 years amounted to 0.49 mm (SD, 0.89) and 0.38 mm (0.65), respectively (Fig. 2). The corresponding bone loss observed at the implant closest to the cantilever unit in group C (implant level) was 0.39 mm (1.04) compared with 0.23 mm (0.67) in group NC (Fig. 3). The reduction in the peri-implant bone height that took place during the 5-year interval at the distal surface of the implant next to the cantilever unit in group C (surface level; Fig. 4) was 0.35 mm (0.95), and the corresponding value in group NC was 0.22 mm (0.79).

The percent of FPDs that had experienced $\geqslant 1$ mm of peri-implant bone loss was 33% in group C and 19% in group NC (Fig. 2). The corresponding figures for the most posterior implant in the FPDs were 33% (group C) and 27% (group NC) (Fig. 3), and for the distal surface of the most posterior implant (Fig. 4) 25% (group C) and 27% (group NC).

No statistically significant differences were found between groups C and NC at any of the three levels of analysis.

The longitudinal bone change that had occurred was also analyzed in relation to the height of the crown/abutment unit (the supra-construction), independent of the presence/absence of cantilever extensions (Figs 5 and 6). The statistical analysis revealed that the height of the supra-construction (<12 or $\geqslant 12$ mm) failed to significantly influence bone loss on the FPD level (-0.61 versus -0.25 mm) but (ii) had an effect on the most posterior implant (implant level) in the FPD (-0.60 versus -0.04 mm; $p<0.05$). It was further observed that 35% of the implants within an FPD with a $\geqslant 12$ mm high supra-construction exhibited $\geqslant 1$ mm of peri-implant bone loss as compared with 17% within FPDs with a lower abutment/crown height. The corresponding figures for the most posterior implants were 40% and 16%.

The stepwise regression analysis performed on the FPD level (Table 3) revealed that the only explanatory variables for the 5-year bone level change that remained in the model when statistical significance was reached ($p<0.05$) were smoking and jaw of treatment. The final model explained only 10% of the variance in the observed bone level change. At the implant and surface levels of analysis, none of the variables reached statistical significance.

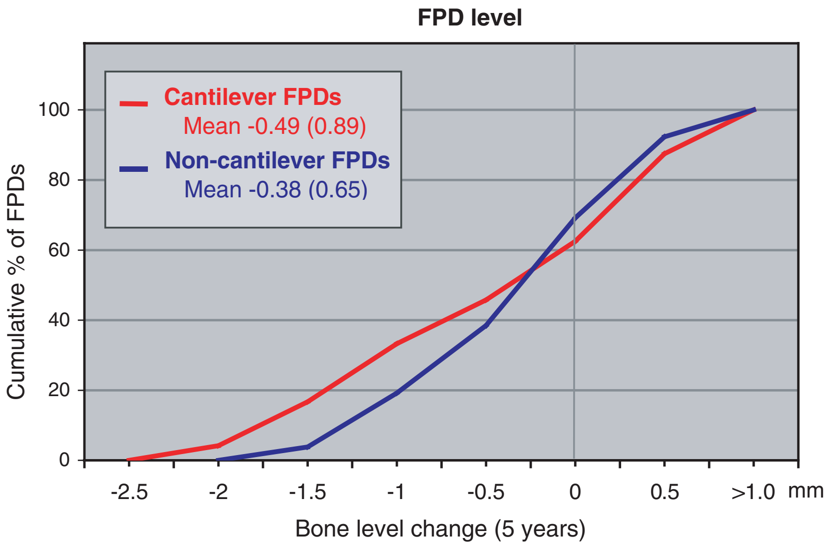

Fig. 2. Cumulative % of fixed partial dentures (FPDs) with and without cantilevers according to peri-implant bone level change at the FPD level. Mean value (SD).

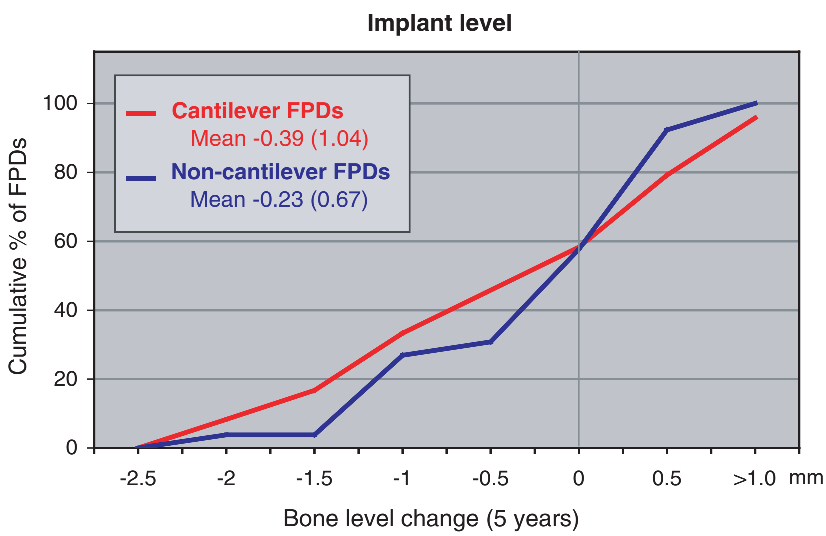

Fig. 3. Cumulative % of fixed partial dentures (FPDs) with and without cantilevers according to bone level change at the most posterior implant. Mean value (SD).

Prosthetic complications

A total of six incidences of technical complications occurred during the

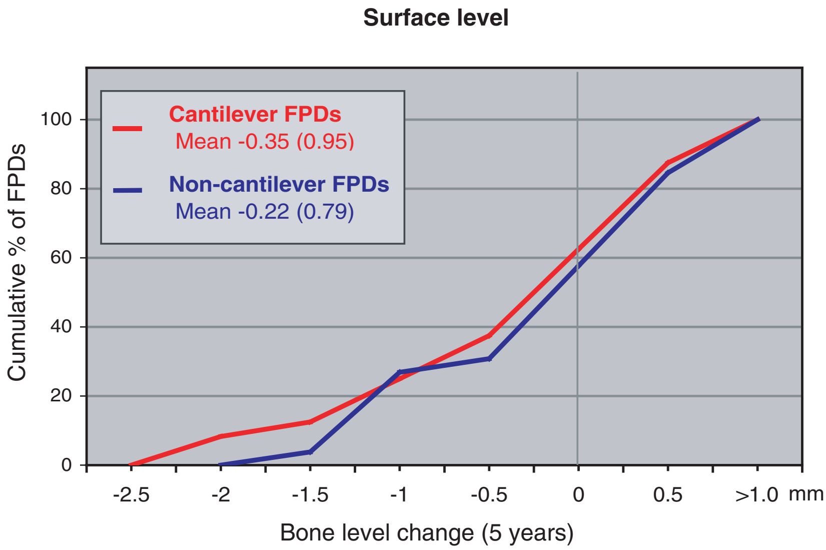

Fig. 4. Cumulative % of fixed partial dentures (FPDs) with and without cantilevers according to peri-implant bone level change at the distal surface of the most posterior implant. Mean value (SD).

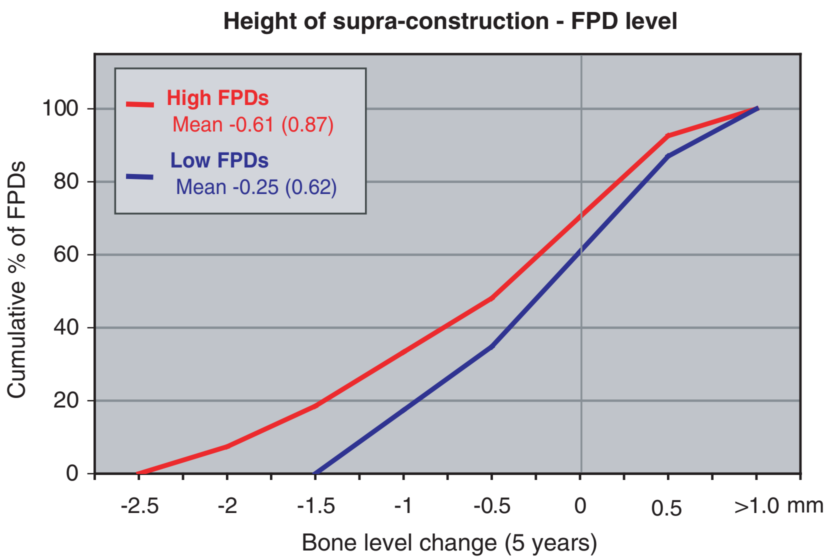

Fig. 5. Cumulative % of fixed partial dentures (FPDs) with <12 mm (low FPDs; $n = 23$) and >12 mm (high FPDs; $n = 27$) height of the supra-implant construction with respect to bone level change. Mean value (SD).

5-year observation period. In three patients, the occlusal screw that attached the FPD to the implant units became loose (two in group C and one in group NC), and in another three subjects minor porcelain fractures were observed and adjusted (one in group C and two in group NC).

Discussion

The observations made in the present study failed to demonstrate a significant influence of the inclusion of cantilever extensions in implant-supported FPDs on the amount of bone loss that had occurred after 5 years in function in patients who maintained a high standard of oral hygiene. Thus, both the bi- and multivariate analyses on the FPD level, the Implant level, as well as the Surface level failed to document significant differences between groups C and NC.

In the present patient sample the mean overall peri-impant bone loss at the implant-supported FPDs after 5 years in function was 0.4 mm. This amount of bone loss is by all standards small and well below the criteria of a proper implant system as described by Albrektsson et al. (1986). Although no statistically significant difference was found in bone level change between FPDs with (group C) and without (group NC) cantilever extensions, there was on all levels of analysis a tendency for FPDs in group C to (i) have experienced a greater mean peri-implant bone loss and (ii) show a higher frequency of implants with ⩾1 mm of bone loss than FPDs without cantilevers. Whether this tendency in fact indicates a potential, negative effect on the peri-implant bone stability by the inclusion of the cantilever extensions may be argued, since the small overall amount of bone loss observed may have hampered the possibility to detect a statistically significant difference between the two study groups. Based on the observed differences between the groups and the variance in the sample, the *post hoc* power analysis revealed that between 102 and 112 subjects per group, depending on the level of analysis, would have been required to demonstrate a statistically significant difference with a power of 0.8. Results from bivariate analyses, however, should be interpreted with caution because skewed distributions of confounding factors may result in erroneous interpretation of a possible relationship between cantilever extensions and bone loss at implants. Thus, factors such as (i) jaw of treatment (Jemt & Lekholm 1993, Naert et al. 2001), (ii) abutment length (Naert et al. 2001), (iii) implant length (Naert et al. 2001), (iv) type of prosthetic material used (Naert et al. 2001), and (v) smoking (Weyant & Bert 1993, Lindquist et al. 1997; for a review see Bain 2003) may influence the amount of bone loss that takes place at endosseous implants. In the current subject sample, 16 out of 24 (67%) FPDs in group C were placed in the maxilla, compared with only 12 out of 26 (46%) in group NC. Furthermore, the mean height of the supra-construction was significantly greater in group C than in group NC (13.8 versus 11.4 mm), and the proportion of smokers differed between the two categories of FPDs (42% in group C and 19% in group NC). There are reasons therefore to assume that these skewed distributions of confounding factors might have, at least in part, accounted for the slightly larger mean amount of bone loss that was noted in group C during the 5-year interval. Consequently, the relative influence of cantilever extensions on the observed longitudinal peri-implant bone level

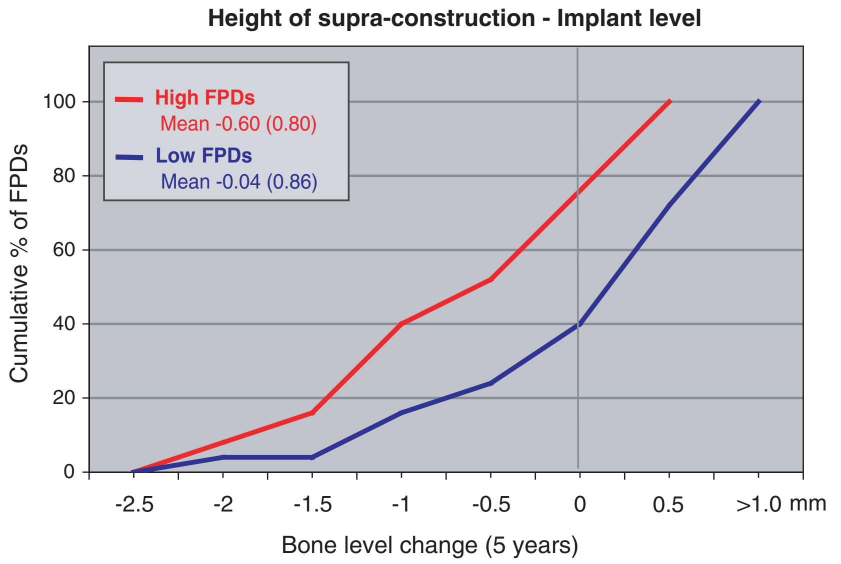

Fig. 6. Cumulative % of fixed partial dentures (FPDs) with <12 mm (low FPDs; $n = 25$) and >12 mm (high FPDs; $n = 25$) height of the supra-implant construction with respect to bone level change (implant level). Mean value (SD).

Table 3. Multiple regression analysis with bone level change at the FPD level (47 subjects) as dependent variable

	Coefficient	SE	*p*-value
intercept	−0.13	0.16	0.427
smoker	−0.41	0.24	0.092
jaw	−0.32	0.22	0.155

$R^2 = 0.10$, $p = 0.032$.
FPD, fixed partial denture.

change was also analyzed in a multivariate model including variables describing both patient and FPD characteristics. When such a model was applied for statistical analysis, cantilever extension could not be identified as a factor influencing bone loss. In fact, the only FPD-related factor that entered into the model was jaw of treatment. This finding corroborates data reported by Jemt & Lekholm (1993) from a 5-year follow-up study of implant-supported FPDs placed in the posterior segments of partially edentulous jaws. Similar to the observation in the present study, the authors found that more pronounced bone loss had occurred at implants placed in the maxilla than in the mandible.

The only other factor that remained in the stepwise regression model was smoking habits. The finding that smoking was a factor associated with increased loss of peri-implant bone support is in agreement with the data by other authors (e.g. Weyant & Bert 1993, Lindquist et al. 1997; for a review see Bain 2003) who suggested that smoking habits – at least in the fully edentulous patient – influenced the rate of peri-implant bone loss. Naert et al. (2001), on the other hand, could not confirm such a negative effect of smoking in the implant treatment of partial edentulous patients.

Several prosthesis-related factors have been suggested to contribute to an increased rate of peri-implant bone loss, e.g. height of the abutments, type of material used in the occlusal surface (porcelain/resin/metal), and type of antagonists (Naert et al. 1992, 2001). In the present sample, the occlusal surfaces of all FPDs were made of porcelain, and at all but one FPD natural teeth occurred as antagonists, either alone or as part of a tooth-supported prosthesis. Furthermore, the height of the supra-construction (crown/abutment unit) failed to significantly influence the peri-implant bone loss on the FPD level, whereas on the implant level (the most posterior implant in the FPD) a statistically significant greater amount of bone loss was observed when the height was ⩾12 mm compared with a height of <12 mm (−0.63 versus −0.02 mm; $p<0.05$). In this context it should be noted that the mean height of the supra-construction was significantly greater in group C than in group NC (13.8 versus 11.4 mm; $p<0.05$), but also higher for FPDs placed in the maxilla than in the mandible (14.6 versus 9.9 mm; $p<0.001$).

Another factor to be considered in long-term studies of implant-supported FPDs is the standards of self-performed oral hygiene maintained by the patients included in the trial. Lindquist et al. (1997, 1988) demonstrated that patients with poor oral hygiene had a significantly increased risk for peri-implant bone loss in comparison with subjects with proper plaque control. The patients involved in the present study had been treated for advanced chronic periodontitis, before implants were placed and the restorative therapy was initiated. In addition, during the 5 years of follow-up they had been provided with regular needs-related professional measures including tooth and implant debridement. The fact that all patients displayed a high standard of self-performed oral hygiene may have positively contributed to the overall small amount of peri-implant bone loss that took place.

In the current sample, six technical complications occurred during the 5 years of observation, and these were equally distributed among groups C and NC. This low frequency of prosthesis-related impediments (0.12 incidence/patient) is in agreement with the data retrieved in a recent systematic review (Berglundh et al. 2002) in which a mean 5-year incidence/patient of 0.24 technical complications was calculated for FPDs supported by implants. Further, Brägger et al. (2001) reported from a 4 to 5-year follow-up of 40 implant-supported FPDs, seven cases of screw loosening and 11 cases of minor porcelain fracture (0.45 incidence/patient). Thus, there are reasons to suggest that technical (prosthesis related) complications may not constitute a major obstacle in implant-supported restorative therapy involving cantilever extensions, provided that the occlusion as well as the bridge attachments are regularly examined and, if necessary, adjusted.

In conclusion, the findings of the present study illustrated that, provided the FPD is (i) placed in patients with a high standard of oral hygiene, and (ii) is designed properly with respect to the occlusal loading, the inclusion of a cantilever unit may not jeopardize the long-term prognosis for implant-supported FPDs.

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