CLINICAL ORAL IMPLANTS RESEARCH

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Impact of implant surface topography: a clinical study with a mean functional loading time of 85 months

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Abstract

Objective: Moderately rough, surfaced implants are widely used. Nevertheless data on long-term soft and hard tissue parameters are still conflicting. The purpose of this study was to evaluate peri-implant bone level and soft tissue integration of anodized vs. turned surfaced implants in the anterior mandible after a mean functional loading time of 85 months.

Methods: Of 114 edentulous patients invited for follow-up, 41,2% were available for recall. Forty-seven patients with a mean age of 71 ± 9 years (14 men and 33 women) received 188 dental implants; All patients were edentulous and prosthetic rehabilitation was carried out by a bar-retained overdenture. Radiographic peri-implant bone level was assessed twice at baseline and recall. Clinical examination contained peri-implant sounding (PPD, BoP) and indexing oral hygiene (mPI).

Results: From baseline up to 85 months two patients experienced implant loss (four implants), which corresponds to an overall-survival rate of 97.9%. No significant differences were found between implant surfaces concerning the clinical parameters, such as plaque, calculus, bleeding on probing and pocket probing depth. The moderately rough surfaced implants showed significantly less decrease in peri-implant bone level (1.53 ± 0.25 mm) than turned surfaced implants (2.42 ± 0.34 mm) ($P = 0.036$). The interaction between the position of the implant and surface topography ($P = 0.037$) as well as the site at the implant ($P = 0.004$) had a significant influence on bone level changes.

Conclusion: Both surface topographies with bar-supported overdentures have excellent long-term clinical outcomes. Moreover, a moderately roughened, anodized surface has beneficial effects in the anterior lower jaw.

Implant therapy conceptions changed during the past decades, whereas patient requirements for aesthetics, function and success predictability remain similar. Nowadays, tools of implant surface modification e.g. sandblasted/acid-etched, dual acid-etched or anodized surfaces allow speeding up patient treatment (Salvi & Lang 2001). Years ago most of the implants were left submerged after surgery. Today immediate or early implant placement and subsequent prosthetic loading without an increase in implant intricacies became common (Degidi et al. 2009). Nevertheless, modifications in therapy concepts require particular evidence not to fulfil industry but patient demands.

In case of implant surface modifications, a more potent bone response to moderately roughened surfaces (S_a 1.1–2 μm) is well investigated (Zechner et al. 2003a; Albrektsson & Wennerberg 2004). Therefore, immediate implant placement and early loading protocols have been facilitated, yet a high value of insertion torque is pre-conditioned (Esposito et al. 2007). However, it is also reported that a surface roughness of more than 2 μm (S_a) is associated with a higher risk of peri-implantitis (Becker et al. 2000). Furthermore, there is evidence in basic research literature that the progression of peri-implant disease, if left untreated, is more pronounced even at implants with a moderately rough surface than at implants with a turned surface (Berglundh et al. 2007; Lang & Berglundh 2011;). Hence, moderate surface modifications may improve implant therapy

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in terms of speeding up the treatment, but may be disadvantageous for the patients prone to peri-implant disease. In a prospective, split-mouth design study no differences could be figured out between two implant systems (machined vs. moderately rough surface). Within this study partially edentulous patients, supplied by fixed implant supported partial prostheses were included in an annual maintenance therapy and followed up for 2 (van Steenberghe et al. 2000) and for 16 years (Jacobs et al. 2010).

Survival rates for dental implants differ in literature. Recent studies on non-submerged implants in upper and lower jaw showed a cumulative survival rate up to 16 years of 82.94% (Simonis et al. 2010). When prosthetic rehabilitation by overdentures in the mandible supported by two implants was performed, the Kaplan Mayer analysis showed a survival rate of 95% over 20 years (Vercruyssen et al. 2010).

The present study aimed at evaluating moderately rough implants in the anterior lower jaw. The edentulous mandible rehabilitated by four submerged, interforaminal screw type implants is frequently used for implant outcome evaluation (Astrand et al. 2004; Zechner et al. 2004; Watzak et al. 2006). To match peri-implant conditions e.g. local bone morphology, hygiene properties and loading situation, patients with fixed implant supported dentures or removable unsplinted prosthodontic devices were excluded.

Peri-implant bone level assessment is widely accepted by radiological imaging techniques. Conventional intraoral or rotational panoramic radiographs are commonly used. In the highly atrophic, anterior mandible the rotational panoramic radiographs are comparable to intraoral radiographs for evaluating peri-implant bone loss (Zechner et al. 2003b).

Evaluation of mucosal conditions around dental implants requires clinical examination. Pocket probing depth (PPD) and bleeding on probing (BoP) are frequently used for peri-implant soft tissue assessment. Moreover, to evaluate oral hygiene, marginal plaque index (mPI) is recommended (Salvi & Lang 2004).

In this retrospective study, patients were invited for a follow-up examination to assess the amount of peri-implant bone loss and mucosal conditions around dental implants in the lower anterior jaw with a mean functional loading time of 85 months. We hypothesize that moderately rough surface topography has a beneficial impact on marginal bone level.

Material & methods

Subjects

Institutional review board approval was obtained for this study (EK 410/2009, Medical University of Vienna) and informed consent was secured from all participants. Overall 114 patients, each treated with four interforaminal screw type implants (Branemark MkIII, either machined or anodized [TiUnite] surface, Nobel Biocare AB^{TM}, Gothenburg, Sweden) in the mandible between May 2000 and March 2004 with an oral rehabilitation by an implant supported, milled bar retained prosthetic device 3 months after surgery were invited to a recall examination.

Exclusion criteria were non-submerged healing, fixed implant supported dentures, or unsplinted prosthodontic designs. Also patients with ridge augmentation procedures prior or during implant surgery were excluded. Furthermore, patients with cancer disease, metabolic disease like diabetes or severe genetic disorder associated with impracticability of personal oral hygiene were excluded.

Forty-seven, (41.2%) of the invited patients with a mean age of 71.2 ± 9.8 years were enrolled for follow-up (33 women, 14 men). Ten patients moved, six patients died and fifty-one patients did not follow the invitation without stating the reason. The majority of enrolled patients (39 [83%]) were edentulous in the upper jaw and rehabilitated by conventional complete maxillary dentures. Four patients (8.5%) had tooth supported, partial dentures, one patient (2.1%) had a tooth supported fixed bridge and three patients (6.4%) were rehabilitated by implant-supported devices (two by bar retained removable devices, one by fixed implant bridge) in the maxilla. A group function with canine guidance was used as occlusal scheme and implemented in all patients.

The group with moderately roughened surface implants consisted of 34 patients (26 female/8 male) with overall 136 anodized surfaced implants (ASI). Thirteen patients (7 female/6 male) with 52 machined surfaced implants (MSI) were considered as control group. All patients answered questions according to their smoking habits and their subjective implant satisfaction. Therefore, patients were asked for their contentment regarding the implant supported prosthetic device and if they would decide on the same treatment again.

Clinical examination

All clinical procedures were performed by a skilled clinician under surveillance of an expert in the field. Marginal plaque index (mPI), pocket probing depth (PPD) and bleeding on probing (BoP) were evaluated. The recall procedure was finished by peri-implant crevicular rinsing with Chlorhexidingluconate 0.2%, and individual oral hygiene instructions in case of peri-mucositis (Wennerberg et al. 2003; Zechner et al. 2004; Watzak et al. 2006). Patients with radiological and/or clinical signs of peri-implantitis were subjected to the common treatment protocol (Lang & Berglundh 2011).

Bone loss evaluation

Each patient underwent a corresponding extra-oral rotational panoramic radiograph (OPG) examination, which was used to evaluate marginal bone level at the time of prosthetic installation (baseline, 4 months after surgery) and at the time of follow-up examination. Please see OPGs in Fig. 4 and Fig. 5 for machined surfaced implants and in Fig. 6 and Fig. 7 for anodized surfaced implants. Peri-implant marginal bone loss mesial and distal to each implant was assessed on radiographs with a precision slide jaw calliper with a maximum resolution of 0.01 mm (Züricher Model, Planer, Austria) as described before (Watzak et al. 2006). Data on bone level changes were assessed, by measuring the vertical distance between the implant-abutment interface and the implant apex. Marginal bone level to implant apex was assessed at the time of follow-up and compared with baseline evaluation. The distance between baseline and follow-up was considered as peri-implant bone loss per site. To obtain the actual bone loss in mm, the dimensional distortion was corrected by the ratio between the apparent implant-dimension and the actual implant size.

Statistical analysis

We applied a mixed model analysis accounting for the problem of correlated measurements within patients. Model assumptions (normality and homoscedasticity) were tested using the Kolmogorov–Smirnov test and Bartlett's test, and none of the tests falsified the assumptions ($P > 0.05$). The main factors of the model are implant surface (turned/anodized), smoking (smoker/non-smoker), implant position (posterior/anterior) and site at implant (distal/medial). Two-way interaction terms included in the model are implant surface vs. implant position and implant surface vs. smoking. Between groups differences were expressed as least square means ± standard error. Clinical parameters in Table 2 are ordinal and were therefore analysed using Fisher's exact test. All P-values were two-sided and $P < 0.05$ was considered as statistically significant. Analysis was done in SPSS 17.0 (SPSS Inc., Chicago, IL, USA).

Results

Forty-seven patients with 188 implants (MSI: 52, ASI: 136) were included in the study. Fourteen male patients (29.8%) and thirty-three female patients (70.2%), with a mean age of 71.2 ± 9.8 years (min. 39 - max. 89 years) at the time of follow-up were enrolled in the study. The recalled patients reported in 72.1% a positive and in 27.9% a negative smoking anamnesis. The mean functional loading time was 85.5 months varying from 64 months up to 117 months. In each group two implant losses were reported with a total of four implants lost in this study. This corresponds to an overall survival rate of 97.9% over 85 months.

There was no association with gender ($P = 0.116$) or position in the jaw ($P = 0.054$) for alveolar bone resorption around the implants. However, a significant interaction between the site of the implant and bone loss was foundin the mesial sites of the implants showing higher values than distal sites ($P = 0.004$) (Table 1). Mesial and distal in this context refers to the mid-sagittal plane inspecting each implant. Also a highly significant influence of tobacco abuse on alveolar bone resorption could be found ($P < 0.001$) (Fig. 1), without significant interaction between smoking and the two groups of implant surface topography ($P = 0.263$) (Fig. 2).

Machined surfaced implants

Thirteen patients (seven women [three smokers]/six men [one smoker]), with a total of 52 turned surfaced implants had a mean functional loading time of 98.8 ± 8.9 months. One patient experienced late implant loss due to peri-implantitis five respectively ten years after prosthetic rehabilitation. Hence, the implant survival rate for implants with a turned surface corresponds to 96.15%. The mean marginal bone level change showed a mean decrease of 2.42 ± 0.34 mm (CI 95% 1.74; 3.10; $P < 0.05$) (Fig. 3). The anterior

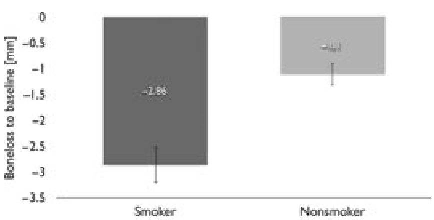

Fig. 1. Overall bone loss to baseline in mm after mean functional loading of 85 months. Smoker: 2.86 ± 0.35 mm vs. Non-smoker: 1.10 ± 0.22 mm.

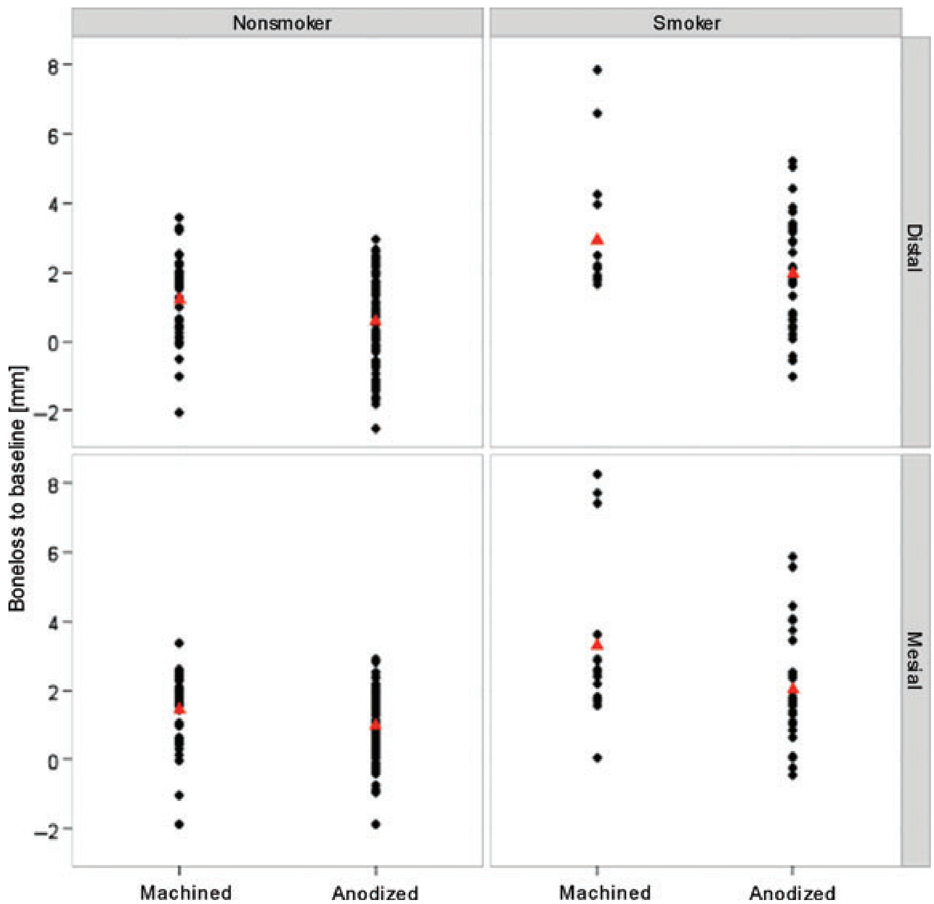

Fig. 2. Scatter plot indicating bone loss to baseline in mm after mean functional loading of 85 months.

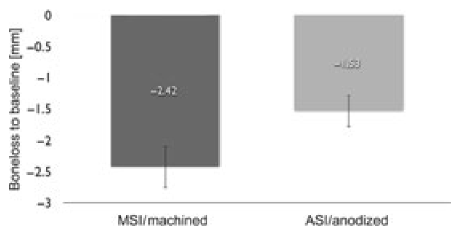

Fig. 3. Overall boneloss to baseline in mm after mean functional loading of 85 months. machined surfaced implants: 2.42 ± 0.34 mm vs. anodized surfaced implants: 1.53 ± 0.25 mm.

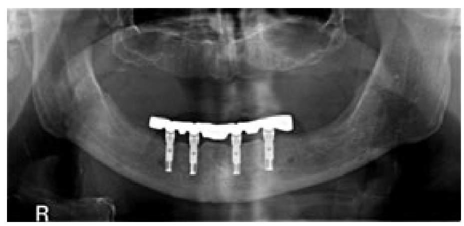

Fig. 5. Case 1: Implants with machined surface at follow-up.

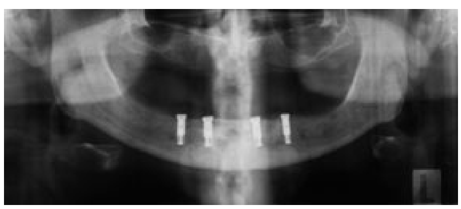

Fig. 4. Case1: Implants with machined surface at time of surgery.

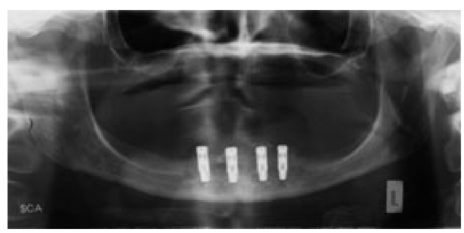

Fig. 6. Case 2: Implants with anodized surface at time of surgery.

implants placed in the lower anterior jaw showed a mean bone level change of 2.64 ± 0.35 mm compared to 2.20 ± 35 mm mm at the posterior placed implants ($P < 0.05$).

Anodized surfaced implants

Thirty-four patients (26 female [6 smokers]/8 male [2 smokers]) with a total of 136 moderately roughened surfaced implants had a mean functional loading of 80.1 ± 11.1 months.

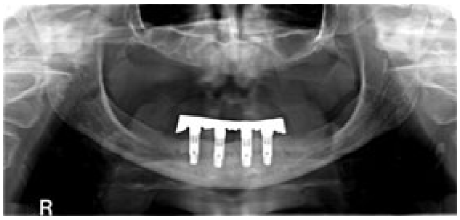

Fig. 7. Case 2: Implants with anodized surface at follow-up.

One patient experienced early implant loss (two implants) at the time of prosthetic loading. Therefore, an implant survival rate of 98.53% was registered for the implants with moderately rough surface topography. The anodized surface implants showed significantly less decrease in peri-implant bone level (1.53 ± 0.25 mm) than turned surface implants (2.42 ± 0.34 mm) ($P = 0.036$) (Fig. 1). The anterior placed implants showed a mean decrease in bone level of 1.53 ± 0.25 mm vs. 1.54 ± 0.25 mm in the posterior region ($P > 0.05$).

The interaction between surface topography and implant position in the anterior mandible showed a significant influence on bone level with the highest resorption rate at anterior turned implants compared with anodized anterior and posterior implant positioning ($P = 0.037$) (Table 1).

The clinical data for turned and anodized surfaced implants are listed in Table 2. Plaque was found on 72% of the evaluated surfaces, 66.7% were on the roughened surfaces and 33.3% were on turned surfaces ($P = 0.101$). Bleeding on probing was found at 40.4% of implant sites of which 76.8% were on anodized moderately rough surfaces and 23.2% on machined surfaces ($P = 0.127$). Mean pocket probing depth was 2.86 ± 0.72 mm at machined implants and 3.13 ± 1.22 mm at anodized implants ($P = 0.740$).

Subjective patient satisfaction: All patients were satisfied with their implant-supported rehabilitation and would conclude on the same treatment again.

Table 1. **Peri-implant bone resorption related to prognostic factors for the mixed model analysis**

	LSM	SE	CI 95%		*P*-value
Surface					
Turned	−2.42	0.34	1.74	3.10	0.036*
Anodized	−1.53	0.25	1.03	2.03	
Non smoker	−1.10	0.22	0.64	1.55	0.000**
Smoker	−2.86	0.35	2.14	3.58	
Implant position					
Posterior	−1.87	0.22	1.43	2.31	0.054
Anterior	−2.08	0.22	1.64	2.53	
Site at implant					
Distal	−1.84	0.22	1.4	2.28	0.004*
Mesial	−2.12	0.22	1.68	2.56	
Surface & implant position					
Turned posterior	−2.20	0.35	1.50	2.90	0.037*
Turned anterior	−2.64	0.35	1.93	3.35	
Anodized posterior	−1.54	0.25	1.03	2.05	
Anodized anterior	−1.53	0.25	1.01	2.04	
Surface & nicotine					
Turned non-smoker	−1.31	0.37	0.56	2.06	0.263
Turned smoker	−3.54	0.56	2.39	4.68	
Anodized non-smoker	−0.88	0.25	0.37	1.40	
Anodized smoker	−2.18	0.40	1.37	3.00	

*$P < 0.05$ was considered significant,
**$P < 0.01$ was considered as highly significant; Mean indicates the least square mean.
LSM, least square mean; SE, the standard error of mean; CI, the confidence interval.

Table 2. **Values of the clinical parameters; all *P*-values are results of Fisher's exact test**

	Total	Turned	Anodized	*P*-value
Plaque index				
0	49	10	39	0.101
	28%	20.4%	79.6%	
1–3	126	42	84	
	72%	33.3%	66.7%	
BoP				
0	102	36	66	0.127
	59.6%	35.3%	64.7%	
1	69	16	53	
	40.4%	23.2%	76.8%	
PPD (mm)	*N* = 171	2.86 ± 0.72	3.13 ± 1.22	0.074

BoP, Bleeding on probing; PPD, Pocket probing depth.

Discussion

This study showed that implants with a turned surface topography in the interforaminal region of the lower jaw have significantly higher bone resorption values than moderately roughened implants in the same region, both inserted in a two stage procedure and supported by milled-bar retained overdentures. Compared with our previous studies regarding the same implant type, peri-implant bone loss encountered in the present study (1.53 vs. 2.42 mm) was comparable to those found in our earlier studies (1.17 vs. 1.42 mm and 1.64 vs. 2.4 mm) (Zechner et al. 2004; Watzak et al. 2006). Nevertheless, our findings are in contrast with a recent study where surface topography had no influence on vertical bone changes (Vroom et al. 2009). This mentioned study investigated dental implants with a moderately roughened implant surface yet the roughening was achieved by a different method and the neck design varies in between the systems. Friberg and Jemt found similar bone loss for both implant surfaces: Uniquely moderately roughened implants were used in critical situations but in contrast with our studies, patients were provided by fixed implant supported prosthesis (Friberg & Jemt 2010).

The influence of the prosthetic rehabilitation design on peri-implant bone loss is frequently examined. For the edentulous lower jaw, Quirynen and colleagues figured out that clinical parameters and bone loss were comparable for implants supporting an overdenture with those supporting a fixed bridge after 10 years of function (Quirynen et al. 2005). Moreover, the prosthetic anchorage concept in case of implant supported mandibular overdentures seems to have no influence on peri-implant bone loss (Weinlander et al. 2010; Naert et al. 2004; van Steenberghe et al. 2001). These findings reflect the impact of local related factors, like bone quality or mechanical strain at the implant site.

Hence, in the present study anterior positioned implants and the mesial site at the implant had an influence on the higher peri-implant bone resorption, especially when turned surface implants were placed. These findings are in line with previous studies that showed the influence of the implant position on bone resorption (Lindquist et al. 1996; Zechner et al. 2004; Watzak et al. 2006). The more extensive bone loss on the anterior implants may be explained by a consequence of tensile forces caused by loading of the posterior cantilever extensions (Lindquist et al. 1996). This effect may be weakened in moderately rough implant surfaces due to a favourable load transfer in between the roughened surfaces and peri-implant bone.

Within the present trial, bone loss evaluation was done using extra-oral rotational radiographs as previously described (Zechner et al. 2003b). It should be taken into account that bone-height measurements on two-dimensional radiographs inherently contain some measurement error (van Steenberghe et al. 2001). In the anterior mandible panoramic radiographs may be superior to intraoral films in that they can be used even in patients with limited mouth opening and atrophy-related elevation of the floor of the mouth (Zechner et al. 2003b). Limitations of this technique are the superimposition of the vertebral column on the anterior region. This distortion may interfere with the evaluation of peri-implant bone loss.

The survival rate varied according to surface topography between 96.15% and 98.53% after a mean follow-up time of 85.5 months. These outcomes are in accordance with previous studies reporting survival rates between 85.5 and 100% for turned surfaces (Rocci et al. 2003; Aalam & Nowzari 2005; Jungner et al. 2005; Watzak et al. 2006) and between 95.5% and 100% for the anodized surfaces (Aalam & Nowzari 2005; Jungner et al. 2005). These survival rates confirm recently published data on positive outcome rates for both surface topographies (Friberg & Jemt 2010).

Evidences support a strong impact of nicotine abuse on bone resorption rates and implant survival (Balshe et al. 2008), especially when implants with a machined surface were placed (Watzak et al. 2006). Compared with the previous study where bone loss was more pronounced in smokers with machined surface implants, in the present study a higher resorption rate was found in smokers independent of the surface used. Nevertheless in this study, smoking assessment followed different criteria than in the previous study, where nicotine abuse was defined at more than 10 cigarettes a day. In a recent report on three different implant supported overdentures in the mandible, smoking almost doubled marginal bone loss irrespective of the treatment strategy chosen (Stoker et al. 2011).

Furthermore, an impact of gender on bone resorption rate was not observed in contrary to Watzak et al. Yet in the present study almost 70% were women and in the previous study the distribution among men and women was almost similar (Watzak et al. 2006).

After such a long recall time the follow-up of 41.2% was lower than in the previous study (62%). Considering the high mean age of 71 years, the gender distribution and the low recall rate could be explained by epidemiologic reasons.

According to soft tissue parameters, the mucosal conditions were not significantly different in between groups. This finding is conclusive with the previous studies (Wennerberg et al. 2003; Watzak et al. 2006; Vroom et al. 2009). Nevertheless the implants have a decreasing roughness towards the neck and the implant collar is machined, which could explain the similar findings in both groups. The amount of patients exhibiting bleeding on probing and presence of plaque was rather high (72% plaque and 40.4% BoP), but the type of oral rehabilitation with an implant-supported, milled bar retained prosthetic device has been shown to be more prone for plaque and calculus retention (Stoker et al. 2011; Krennmair et al. 2012). Therefore, unsplinted prosthetic designs supported by two or four implants seem to be a useful treatment option to prevent mucosal inflammation as a matter of plaque retention.

The present study showed that roughened implant surfaces are more favourable considering vertical bone changes. Evidence exists that soft tissue parameters in a prosthetic rehabilitation favourable to plaque and calculus retention are not affected by moderate surface modifications.

Conflict of interest

All authors were funded by their institutions (Bernhard Gottlieb University Clinic of Dentistry, Medical University of Vienna; Ludwig Boltzmann Institute). The authors declare that there is no affiliation or any other conflict of interest. Implementation of the present study happened without any financial industrial support.

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