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Reaction of crestal bone around implants depending on mucosal tissue thickness. A 1-year prospective clinical study

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SUMMARY

Purpose. The aim of this paper was to distinguish what kind of mucosal tissue, measured at the top of the crest can be referred to as thin, medium or thick and its influence on crestal bone loss around dental implants after a 1-year follow-up.

Materials and Methods. Totally 64 implants were evaluated in 26 patients. 32 implants (test group) were placed about 2 mm supracrestally and 32 implants (control group) were positioned equal to the bone level. Mucosal tissues at a time of implant placement were divided into 3 groups - thin, medium and thick. Crestal bone changes were measured at implant placement and after a 1-year follow-up.

Results. Mean bone loss around test implants in thin tissue group (up to 2 mm) was 1.35 mm ±0.33 SD, in medium thickness group mean bone loss was 0.32 mm ±0.44 SD and 0.12 mm ±0.16 SD of bone loss was registered in thick tissue group (3.1 mm and more). Mean bone loss around control implants in all 3 groups was as follows: 1.8 mm ±0.52 SD in thin, 1.62 mm ±0.63 SD in medium and 1.55 mm ±0.47 SD in thick tissue group. ANOVA analysis showed statistically significant differences between 3 groups of thickness, as crestal bone loss around test implants is concerned. ($F_{[2,29]}$=37.3; P= .000). In control implants bone loss did not vary between 3 groups of tissue thickness ($F_{[2,29]}$=0.73; P= .503).

Conclusions. It can be concluded that initial tissue thickness can influence crestal bone changes around implants.

Key words: biologic width, crestal bone loss, implant, abutment, peri-implant soft tissues.

INTRODUCTION

Formation of soft tissue seal around implants was shown to be a complex and long lasting process. It starts immediately after the placement of a non-submerged implant as gingival tissues are sutured [1]. If a two-stage procedure is applied, the structuring of biologic width begins with the connection of healing abutment during the second stage surgery [2]. At that time, the implant becomes exposed to adverse oral environment; therefore, a particular protective mechanism has to be organized to avoid direct contact of the bone with other oral tissues. Epithelial proliferation with further attachment, followed by collagen fiber organization results in the establishment of stable dimension of about 4 mm in vertical extension, responsible for protection of alveolar bone around osseointegrated implants [3]. The protective abilities of biologic width were well described in a recently published evidence-based review, which critically evaluated the function of soft tissues around implants, analyzed in animal and human histology and clinical trials, and confirmed that

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biologic width serves as a defensive instrument for osseointegration [4]. Thus, maintaining healthy and undisturbed biologic width around implants is considered crucial for successful long-term implant treatment [5;6].

Some studies have observed that morphogenesis of per-implant mucosa may involve crestal bone loss. Berglundh et al. [2] related this marginal bone recession to the thickness of soft tissues. They reported that in thin tissues formation of biologic width after the second stage surgery resulted in significant bone resorption, in contrast to the thick tissue group, where no statistically reliable bone loss occurred. The preceding study by Abrahamsson et al. [6] also noticed angular bone defect formation around implants with thin soft tissues; however, no further investigation or analysis was performed. That is similar to the observations from Oakley et al. [7] experiment, which showed that re-establishing of biologic width around teeth after a surgical crown lengthening procedure engaged marginal bone loss. Hence, it seems that correlation between the thickness of gingival tissue and subsequent bone loss around implants does exist, at least at the level of evidence of animal histological studies. Of course, if this association was confirmed by clinical trials, which are absent in this particular field of implant dentistry, some change in implant placement strategy or research methods could be expected.

Historically, two types of gingival phenotype are distinguished: thin, which is described as prone to recession with sharp papillae; and thick, generally stable with blunt interdental tissue [7;8]. However, there is some controversy in literature about what kind of soft tissue thickness could be referred to as thin or thick. Muller at al. [10] reported that about 80% of all examined soft tissues are of mixed pattern, which cannot be strictly attributed to thin or thick biotype. In addition, no firm criteria for distinction between thin and thick tissues could be found in the literature. Furthermore, usually facial or palatinal/lingual tissue set was investigated by probing with a needle or an endodontic instrument [9;10], while gingival tissue at the top of the crest usually remained out of the scope of authors' interest.

In the implant-related study the distinction point between thin and thick tissues was shown to be about 2 mm [11]. However, after healing, the mean tissue thickness around test implants was about 2.5 mm. This discrepancy may lead to false interpretations; thus, the subject matter needs to be clarified.

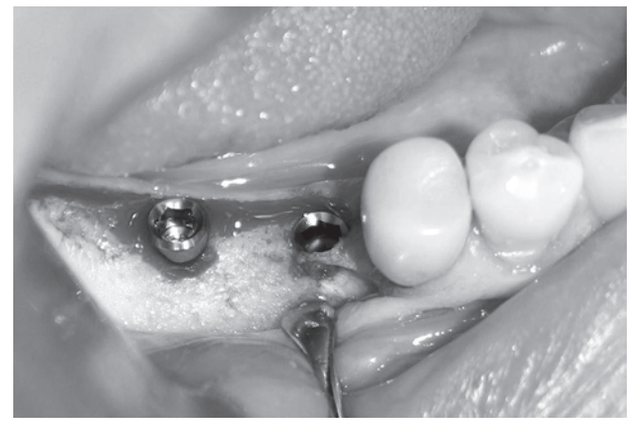

Fig. 1. Position of control (right) and test (left) implants

Therefore, the aim of this paper is to distinguish what kind of mucosal tissue, measured at the top of the crest can be referred to as thin, medium or thick. Additionally, this study tests the influence of various soft tissue thicknesses on crestal bone changes around implants.

MATERIALS AND METHODS

Patients

Subjects were randomly selected among partially edentulous patients, who attended Vilnius Implantology Center Clinic (Vilnius, Lithuania) for implant treatment. Inclusion criteria were: (1) eighteen years of age or more; (2) fully healed bone sites (at least 6 months after tooth extraction); (3) no bone augmentation procedures before and during implant placement; (4) edentulous gap for at least 2 implants in any region of the mouth with minimum 3 mm distance in-between and minimum 1 mm range from adjacent tooth/teeth; (5) no medical contraindication for implant surgery; (6) signed informed consent form for participation and permission to use obtained data for research purposes.

Patients were excluded; if they did not meet requirements listed above and additionally had: (1) poor oral hygiene; (2) symptoms or history of periodontitis or peri-implantitis treatment; (3) poor cooperation, required for the study; (4) smoking; (5) diabetes; (6) alveolar ridges with bone defects at implantation sites; (7) poor primary stability, precluding healing abutment connection at a time of surgery; (8) absence of attached gingiva or presence less than 2 mm.

Study design

Two implants were placed adjacent to each other. The test implant was placed about 2 mm

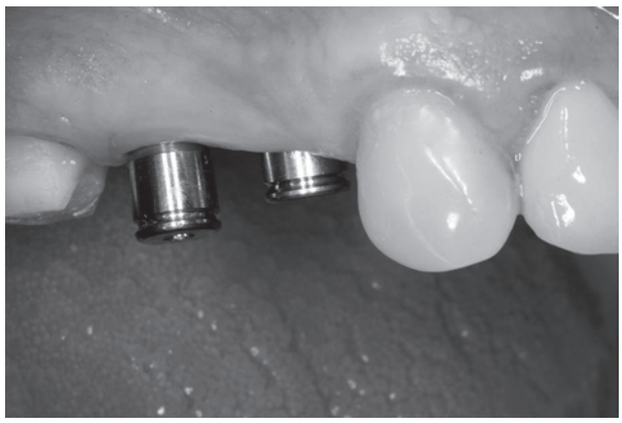

Fig. 2. Healed tissues around control (right) and test implants

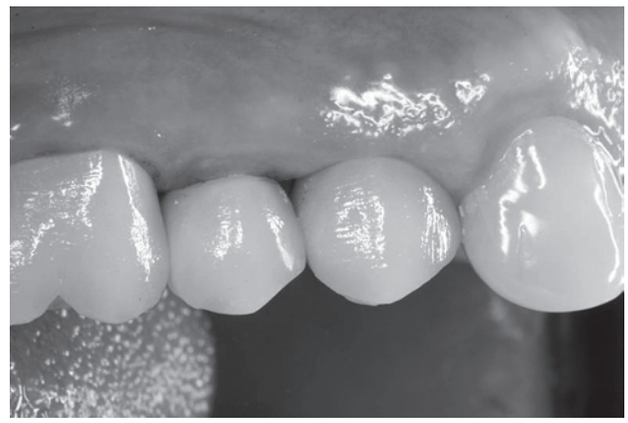

Fig. 3. Implants restored with metal-ceramic single crowns

supracrestally and a control implant was positioned at the crestal level, according to standard insertion protocol (Figure 1). Randomization was performed in two levels – first, cases for the study were randomly selected among partially edentulous patients, who attended clinic for treatment. Secondly, patient birth date was used to determine which implant will be allocated as test implant and positioned supracrestally. If a patient's birth year ended with an even number (e.g., 1970), the first implant was considered to be test one and positioned 2 mm above the bone crest. If the number was odd (e.g., 1971), the first implant was placed equally with crest and served as a control. In both cases second implant was inserted conversely.

Implant placement

Implants with internal hex (Prodigy; BioHorizons, Alabama, USA) were placed in a single stage (non-submerged) technique by an experienced surgeon. All patients received a prophylactic dose of antibiotics of 2 g amoxicillin (Ospamox; Biochemie, Austria) 1 hour prior to the surgery. After the administration of 4% articaine solution (Ubistesin; 3M ESPE, Germany) for local anesthesia, a mid-crestal incision on the center of edentulous ridge was performed. The flap was raised in two stages:

1. Buccal flap was raised and mucosal thickness of unseparated palatal-lingual flap was measured with 1.0 mm marked periodontal probe (Hu-Friedy, Chicago, IL, USA) at the bone crest in the place in the center of future implant placement

2. Palatal-lingual flap was raised to expose implant site.

The osteotomy site was measured to allow a minimum 3 mm distance between the two implants, 1 mm range from adjacent tooth/teeth and 1 mm space between buccal and lingual/palatal crest of the alveolar ridge and implant..After implant placement, healing abutments were connected and 5/0 interrupted sutures (Polysorb; USS-DG, Norwalk, CT) were placed..Immediately after suturing, radiographs were taken using RVG Windows Trophy 5.0 (Trophy Radiologie Inc., Paris, France) periapical films in high-resolution mode. Patients were instructed to rinse the operated site with 0.12% chlorhexidine-digluconate (Fresenius Kabi Norge; AS, Norway) solution twice a day for a week. For pain control, patients were prescribed 400 mg of ibuprofen (Ibumax; Vitabalans Oy, Finland) to be taken as needed. Patients were advised to minimize trauma to the site without special diet introduced. The sutures were removed 7-10 days following the surgery.

Restorative procedures

Prosthetic procedures were initiated following 2 months of healing in the lower jaw and 4 months in the upper jaw (Figure 2).. Porcelain-fused-to-metal fixed restorations were fabricated and cemented with resin modified glass-ionomer cement (Fuji Plus, GC, Japan) on modified standard abutments (Figure 3). After the cementation, radiographic images were taken to ensure abutment seating and check for residual cement. After the prosthetic treatment, the patients were instructed on cleaning implant-supported restorations.

Follow-up examinations and maintenance schedule

Patients were recalled 6 and 12 months after prosthetic treatment for oral hygiene and evaluation. At each visit the restorations were evaluated for mobility, peri-implant soft tissue condition and patient satisfaction. Intra-oral radiographs were taken to evaluate bone changes.

Radiographic assessment and measurements

Intra-oral radiographs were taken using a paralleling technique with Rinn-like film holder in high-resolution mode.. The images were obtained to make sure implant/abutment interface and the threads were clearly visible. Before measurement the parallelism of all intra-oral radiographs was evaluated. Radiological evaluation and measurements were performed by one of the examiners using RVG Windows Trophy 5.0 software measurement program with a magnification (×6). Two images were selected for calculation of crestal bone changes, such as *(1)* after implant placement, and *(2)* after 1 year post reconstruction. Before calculation of the crestal bone changes the calibration of RVG images was performed, using calibration program in the Trophy RVG software.

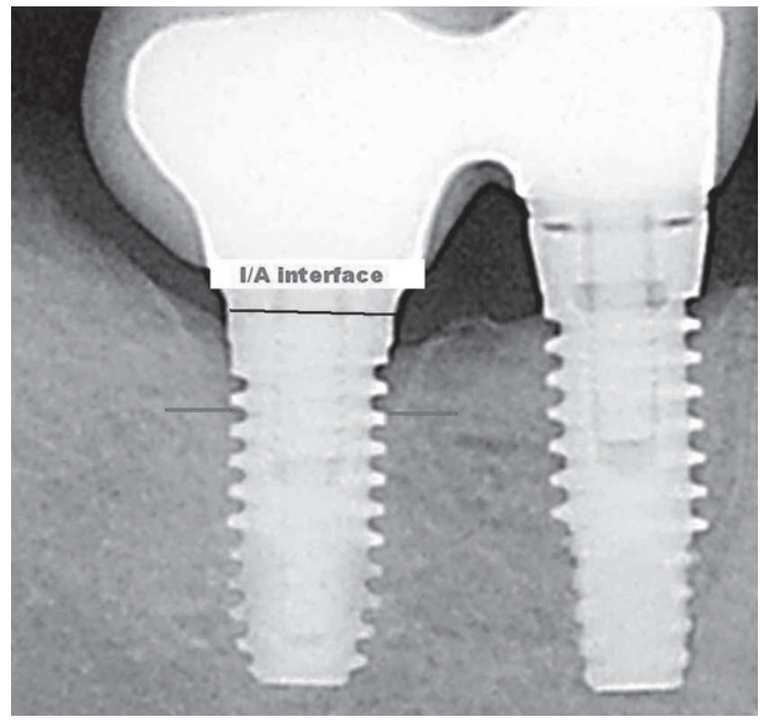

Fig. 4. Crestal bone loss around control (left) and test implants

The diameter of implants was used for calibration as a reference point. Implant/abutment interface was chosen as a starting point for a calculation, as it was easily identified in parallel RVG image (Figure 4). The first measurement demonstrated the distance between implant/abutment junction and crestal bone after implant placement in distal and medial aspects. The second measurement evaluated the same distance after 12 months of follow-up. The difference between these values showed the amount of proximal actual amount bone loss. The measurements were repeated after 1 month.

Statistical analysis

Data were analyzed using SPSS 15.0 Windows (SPSS; Chicago, IL, USA) statistical software. The single implant was treated as a statistical unit. Initially, each variable was assessed using parametrical methods. As variables appeared to be normally distributed frequencies were calculated. Next, a two-way analysis of variance (ANOVA) was conducted to assess mean differences within the groups. The statistical significance between groups was assessed using F test.

For comparison of continuous variables means and standard deviation were calculated. Later, continuous variable were converted in two discreet ordinal values, using rules of distribution analysis. At first stage minimum and maximum was found, after those, median and lower and upper quartiles were calculated. This allowed distributing all mucosal thickness measurements into 3 distinct groups – thin, medium and thick.

All the test implants were distributed into 3 groups according to the initial tissue thickness – thin (up to 2 mm), medium (2.1-3.0 mm) and thick (3.1 mm or more) group. The mean differences were considered statistically significant at P=0.05 with a confidence interval of 95%. To visualize the differences 95% confidence intervals were plotted. The intra-examiner agreement was determined by the second measurement which was performed after a one-month interval. The mean difference between the measurements was 0.1 mm ±0.16. All the measurements were reproduced with the difference of ±0.5 mm.

RESULTS

Initially, 34 patients agreed to participate in the study and received 78 implants - equal number of tests and controls. A group of 3 patients with 6 implants placed was excluded from the study on the basis of refusal to attend follow-up checkups and change of living place. Additionally, 3 cases, complied of 6 implants were removed from the study, because radiographic images of implants they received were not sufficiently parallel to correctly calculate crest bone changes. One case (2 implants) was excluded after statistical analysis, as bone loss around control implant was abnormal,

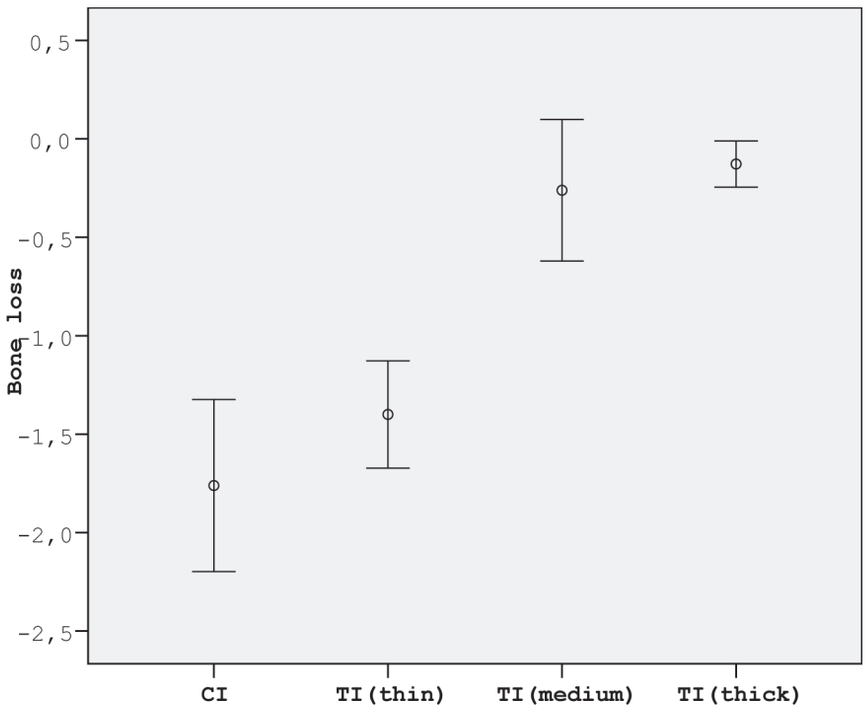

Fig. 5. Differences between test and control groups (CI – control implants; TI – test implants)

compared to mean distribution. Therefore, the final sample included 26 patients consisting of 14 males and 12 females. Subjects' average age was 45.6 y., ranging from 23 to 71 years at the beginning of the study. In total 64 implants (32 test and 32 control) were evaluated. A pair of implants (test and control) was treated as a single case. Mandible group consisted of 27 cases (54 implants in total; 84%) with 5 cases assigned to maxilla group (10 implants; 16%). Depending on the quadrant of the jaws, the implants were distributed in the following way: I quad. – 2 cases (4.3%), II – 3 cases (9.4%), III – 15 (46.9%) cases, and IV – 12 cases (37.5%).

All 64 implants integrated successfully, as evaluation under implant success criteria was applied. Twelve single crowns (18.8%), eighteen 2-unit splinted crowns (56.3%) and eight 3-unit (25%) fixed partial dentures were constructed afterwards. Overall, the implant survival rate after 1 year of function in test and control groups was 100%. Survival was defined stable functioning implant in the mouth at a time of evaluation. No prosthetic complications were recorded at follow-up visits.

Table 1. Distribution of gingival tissue thickness in 3 groups

Groups	Mean	N	SD
up 2	1.875	12	.2261
2.1-3.0	2.958	12	.1443
Over 3.1	3.625	8	.2315
Total	**2.719**	**32**	**.7399**

Table 2. Crestal bone loss around test and control implants in 3 groups

3 Groups		Bone loss TI	Bone loss CI
up to 2	Mean	-1.35	-1.83
	N	12	12
	Std. Deviation	0.33	0.52
2.1-3.0	Mean	-0.32	-1.62
	N	12	12
	SD	0.44	0.63
over 3.1	Mean	-0.12	-1.55
	N	8	8
	SD	0.16	0.47
Total	Mean	-0.66	-1.68
	N	32	32
	SD	0.64	0.55

The distribution and frequency of thin, medium or thick gingival pattern is demonstrated in Table 1. Mean bone loss around test and control implants in 3 tissue thickness groups can be seen in Table 2.

ANOVA analysis showed statistically significant differences between 3 groups of thickness, as crestal bone loss around test implants is concerned. ($F_{[2,29]}$=37.3; P= .000). In control implants bone loss did not vary between 3 groups of tissue thickness ($F_{[2,29]}$=0.73; P= .503). Test implant error bar interactive graphics showed the statistically significant differences of bone loss between thin/medium and thin/thick groups. There was no reliable distinction between medium and thick tissue. Control implants error bar analysis showed no differences between 3 groups (Figure 5).

DISCUSSION

The current experiment investigated the influence of thin, medium and thick gingival tissues on crestal bone loss around implants. It was observed that crestal bone response varied in all the three groups – from 1.35 mm loss in the first group down to 0.32 mm in the second, and 0.12 mm in the third group. The major findings showed increasing marginal bone loss around test implants positioned about 2 mm above the bone level, as the thickness of gingiva before implant placement

was decreasing. If an implant was placed in the site with gingival tissue thickness of 2 mm or less, statistically significant increase of crestal bone loss was recorded, compared to the medium and thick tissue groups or control implants. This is in agreement with the Bergludh and Lindhe [2] animal study, which, despite methodological disparities with the current experiment (second stage surgery, peri-implant tissue trimming), showed the potential of 2 mm or less thickness soft tissue to cause crestal bone loss in the process of biologic width formation. The further support for this argument can be found in another study, involving nonhuman primates. Oakley and co-authors [7] observed the formation of the biologic width around teeth after clinical crown lengthening procedure, during which gingival tissues were thinned and the connective tissue around the tooth was removed. The results showed that after osteoectomy, junctional epithelium migrated to the bone level and connective tissue re-established within a 6 months period due to bone resorption [12]. The excision of connective tissue of peri-implant mucosa in Beglundh and Lindhe study with implants could be compared with the removal of the gingival connective tissue during clinical crown lengthening procedure in Oakley et al. [7] study. It is possible, that the removal of connective tissue around implants caused the bone resorption to create the room for the establishment of the new connective tissue zone, as around teeth.

In contrast, the medium tissue thickness group, consisting of gingiva from 2.1-3.0 mm, had no statistically different outcome, compared to thick tissue group, although mathematical decrease of bone loss with the enlargement of tissue thickness was recorded. The implants in the thick tissue group (3.1 mm or more) had the least bone loss on average and in some cases even bone gain was recorded. The study revealed similar reaction of bone to medium and thick gingiva and completely diverse behaviour of crestal bone around implants with thin biotype. The results of the study are contrary to conclusions from number of animal experiments, showing that placement of implant-abutment interface above bone level, precluded or at least significantly reduced crestal bone loss afterwards [13-19]. Therefore, it can be claimed that the initial tissue thickness is an additional factor in early crestal bone loss etiology.

Another significant result was the constant bone loss around control implants positioned equally with bone level in all 3 tissue thickness groups. No statistically reliable changes in the amount of bone loss could be recorded in thin (1.83 mm), medium (1.62 mm) or thick (1.55 mm) gingival tissues. This can be explained by the position of the control implants, as they were placed equally with the bone crest, thus approximating implant-abutment interface (microgap) to the bone. Microgap is the special feature of two-piece implants and it's been related to crestal bone loss. *In vitro* studies have shown that due to implant-abutment interface there is a bacterial leakage along all the system [20;21]. This leakage is responsible for abutment-related inflammatory cell infiltrate formation in soft tissues adjacent to microgap, as described in numerous histological animal studies [22-24]. In contrast one-piece implants, which bypass the effect of microgap, do not show the development of specific inflammatory cell infiltrate at the bone crest [25;26].

Herman and collaborates in a series of animal experiments did prove that placement of implant-abutment interface at the level of bone or more apically may result in significant marginal bone reduction [27-29]. Pathogenesis of microgap related bone loss was described by Broginni et al. [30]. It was suggested that inflammatory cells promote osteoclasts formation and draw, which may result in alveolar bone loss. This hypothesis was confirmed in a later experiment which showed the capacity of deeper-placed implants to accumulate more neutrophils, more inflammation, and thereby cause more bone loss [31].

Polished implant neck is advanced as another factor, playing role in early crestal bone loss etiology. Historically implant neck was manufactured with polished surface to reduce plaque accumulation, if implant becomes exposed to oral environment, as a consequence of alveolar bone loss. However, clinical trials, which studied bone levels around implants with polished collars, have shown the tendency for hard tissue resorption in contact with machined surface. Hammerlle et al. [28] reported that ITI implants did not maintain bone, when implant was restored, despite countersinking. Recent study by Shin et al. [29] concluded similar results that implants with rough neck experienced less bone loss, compared to polished neck fixtures. The pathogenesis of polished surface related bone loss is described in review article by Wiskot and Belser [32]. It was hypothesized that machined implant surface cannot effectively distribute occlusal stress between bone and smooth titanium surface; "stress shielding" is created and results in bone loss.

Two-piece implants used in the current study have a 0.5 mm polished part which was submerged under the crest level at the placement. Thus, the determined bone loss around the control implants could be considered as interaction between both factors.

The placement of implants at the bone level is used as a common practice standard, recommended by majority of manufacturers and studies. However, supracrestal implant placement cannot be considered as experimental, although not in agreement with traditional approach. Davarpanah et al. [31] proposed supracrestal implant placement, as a possibility to reduce bone resorption and achievement of better clinical crown/implant relationship, as longer implant placement becomes possible. Martinez et al. [32] suggested avoiding crestal or subcrestal implant position in regions with limited bone height and poor quality, if only short implants can be used without difficult bone augmentation procedures, as crestal bone loss around short implant can significantly jeopardize percentage of bone-to-implant contact and result in unfavorable biomechanics. Author advised to place implants supracrestally and maintain stable crestal bone [33;34].

Thus it can be concluded that supracrestal implant placement is one of the treatment modalities, having its place in clinical practice.

Bone loss around implants can be reported in two different ways. Some studies state separate measurement of distal and medial sites of implant [35], others show combined numbers per implant [36-38]. Reporting bone loss medially and distally seems more precise, as measurements between sites can vary. The reason for such disparity might be the shape of alveolar ridge. Flat ridge is optimal; however not available in most of the cases. Sometimes implants are placed on ascending bone crest. This results in different implant/abutment junction position mesiodistally in relation to the bone level.

On the other hand, the combined measurement is more convenient to understand, to relate and to compare with outcomes of other studies.

The second purpose of the study was to define what kind of crestal gingival thickness can be described as thin, medium or thick. As review of literature indicates, there no studies, which try to divide the thickness of gingival tissues at the crest, according to magnitude of bone loss, although, some studies have proposed to distinct thin tissues from thick with the help of periodontal probe at the facial aspect. The peri-implant biotype was categorized as thin, if the outline of the underlying periodontal probe could be seen through the gingiva, and thick if the probe could not be seen [39]. However, the measurement of the differences between both biotypes was not attempted.

Thus, all tissues were assigned to 3 groups: thin group with tissues up to 2 mm; medium thickness from 2.1-3.0; and thick group with tissue 3.1 mm or more. The division into 3 types of tissue thickness was partly based on the outcome of Berglundh and Lindhe [2] study, which defined thin tissue as that of 2 mm thick, and that of 3.3 mm in thickness as thick tissue. It is obvious that tissue width can vary within the interval from 2 to 3.5 mm; therefore, the division into 3 groups seems reasonable. The frequency of each group within all samples was very similar. The thin and medium groups consisted of 12 samples each and the thick group had 8 cases. However, clinical results failed to prove the justification of this assignment into 3 groups, as there was no difference between medium and thick group.

The thickness of peri-implant tissues was measured by Kan et al [40]. He evaluated the difference between thick and thin biotype of peri-implant mucosa by probing around restored implants in anterior region. Results have shown significantly deeper probing depths around implants with thick biotype. However, the primary width of the mucosa before implant placement was not registered. Neither, the bone loss or position of the implant/abutment interface in relation to bone crest was reported.

Cardaropoli et al. [39] performed similar prospective study, measured mucosa before implant placement and calculated bone loss after 1-year follow-up. However, the study design did not include elimination of microgap influence, as all implants were placed equally with the bone, therefore results can not be compared to the findings of current experiment.

CONCLUSIONS

Within the limits of the presented study, the following conclusions can be drawn:

1. The initial gingival tissue thickness can influence marginal bone level around supracrestally placed implants. Additional crestal bone loss may occur if gingival tissue at the time of implantation is up to 2 mm at the crest. If soft tissue is medium or thick, no significant bone level reduction should be expected around implants, positioned about 2 mm above bone level.

2. It may be not rational to divide gingival tissue thickness measured at the bone crest into 3 groups – thin (up to 2.0 mm), medium (2.0-3.0 mm) and thick (3.0 mm and more), because there was no difference between crestal bone loss around test implants, placed in medium and thick tissues. It seems that traditional division of mucosal tissues into thin and thick by the measurement of 2 mm remains the reference point.

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