CLINICAL ORAL IMPLANTS RESEARCH

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Radiological comparison of laser-microtextured and platform-switched implants in thin mucosal biotype

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Abstract
Objective: To compare how laser-microtextured implants and implants with platform switching maintain crestal bone stability in thin peri-implant tissues.
Material and methods: Thirty laser-microtextured implants of 4.6 mm diameter (Tapered Internal Laser-Lok, BioHorizons, Birmingham, AL, USA; Group 1) and 30 implants with platform switching of 5/4 mm diameter (Certain Prevail; Biomet/3i, Palm Beach Gardens, FL, USA; Group 2) were placed in 30 patients (12 males and 18 females, mean age 42.3 ± 2.4) with thin mucosal tissues (≤2 mm). Implants were placed in posterior mandible in one-stage approach and after integration were restored with screw-retained metal-ceramic restorations. Radiographic examination was performed after implant placement, 2 months after healing, at prosthetic restoration delivery and after 1-year follow-up. Mean crestal bone loss was calculated, Mann–Whitney *U*-test was applied, and significance was set to 0.05.
Results: After 2 months of healing, the crestal bone loss was 0.71 ± 0.25 mm SD (range, 0.25–1.6 mm) and 1.02 ± 0.25 mm SD (range, 0.6–1.55 mm) in groups 1 and 2, respectively ($P = 0.001$). At restorations' delivery, the crestal bone loss was 1.10 ± 0.30 mm SD (range, 0.65–1.85 mm) and 1.37 ± 0.27 mm SD (range, 0.90–1.80 mm) in groups 1 and 2, respectively ($P = 0.001$). After 1-year follow-up, the crestal bone loss was 1.41 ± 0.42 mm SD (range, +0.1–2.30 mm) and 1.43 ± 0.23 mm SD (range, 1–1.80 mm) in groups 1 and 2, respectively ($P = 0.976$).
Conclusions: Laser-microtexturing of implant collar or platform-switched implant/abutment connection did not eliminate crestal bone loss, if at the time of implant placement vertical soft tissue thickness was ≤2 mm. However, laser-microtextured implants may present less proximal bone loss than platform-switching implants in the period before implant loading.

Continuous design modifications are significantly improving the function of dental implants. Introduction of platform-switching concept into implant manufacturing was one of the most common changes during past decade. It was proposed to use prosthetic abutment of a smaller diameter, than that of an implant, hoping that platform switching will allow the horizontal distraction of implant-abutment microgap away from bone crest (Lazzara & Porter 2006). Microgap was found to be one of the major factors responsible for bone remodeling in apical direction (Hermann et al. 2000, 2001a,b; Broggini et al. 2003, 2006), therefore its dislocation should provide more stability to the bone level. Many clinical studies and systematic reviews have showed that modification of implant–abutment junction significantly reduces crestal bone loss in comparison with regular connection implants (Canullo & Rasperini 2007; Cappiello et al. 2008; Prosper et al. 2009; Atieh et al. 2010; Canullo et al. 2010; Al-Nsour et al. 2012; Annibali et al. 2012), leading to an increased use of platform-switching idea in the daily clinical practice.

Another modification, designed to improve crestal bone levels, is implant neck microtexturing with laser. Laser-ablated microgrooved implant surface depths and widths in range of 8–12 μm should allow direct contact of connective tissue to the implant collar, thus reducing the epithelial downgrowth and crestal bone resorption (Nevins et al. 2008). The evidence from histological human and animal studies with dogs demonstrated the supracrestal connective tissue attachment around implants with laser grooving (Nevins

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et al. 2010, 2012). Clinically it was shown that probing depths and crestal bone loss adjacent to the laser-microtextured collar implants were lower than control implants with polished coronal parts (Pecora et al. 2009; Botos et al. 2011). However, several research groups have revealed that if implants are placed in prevalently thin soft tissue biotype, crestal bone loss develops during formation of the biologic width (Linkevicius et al. 2009; Vandeweghe & De Bruyn 2012; Vervaeke et al. 2014). The latest study has shown that platform switching in bone level implants was not effective in reduction of crestal bone loss extent, when implants were placed in thin soft tissues (Linkevicius et al. 2014). It is becoming clear that the positive impact of technical implant modifications' on crestal bone loss reduction should be evaluated with soft tissue thickness factor having in mind. Subsequently, the question arises whether laser-microtexturing of the collar would effectively reduce crestal bone loss in thin soft tissue biotype, as tissue thickness factor was not evaluated in prior clinical studies with laser-modified implants.

Thus, the aim of this study was to investigate how implants with laser-microtextured collar and platform-switched fixtures maintain crestal bone stability in thin mucosal tissues. Null hypothesis was raised that platform switching and laser-microtexturing do not reduce bone resorption.

Material and methods

Sample size calculations were performed with G × Power 3.1 software, based on the data from previous clinical study (Linkevicius et al. 2010). It was determined that at least 30 patients should be involved to detect 1 mm difference in marginal bone levels to provide 80% power to the study, assuming an error rate of 5% and a within-patient variation (SD) of 0.45 mm.

Subjects for the study were selected among patients in Vilnius Implantology Center Clinic, Vilnius, Lithuania. The protocol for this study was approved by the Vilnius regional ethical committee for biomedical trials (No.158200-07-512-149). Inclusion criteria were as follows: (1) vertical thin soft tissues with thickness 2 mm or less; (2) no <18 years of age; (3) generally healthy patients, no medical contraindication for implant surgery; (4) missing teeth in lower jaw posterior area, premolar or molar region; (5) minimum of 7 mm bone width; (6) edentulous gap for two implants with minimum 3 mm distance inbetween and minimum 1 mm range from adjacent tooth/teeth; (7) healthy soft tissue (BOP < 20%, PI < 25% CPITN < 2) (Ainamo et al. 1982); (8) minimum 4 mm keratinized gingiva buccally and lingually; (9) no bone augmentation procedures before and during implant placement; (10) signed informed consent form for participation and permission to use obtained data for research purposes; (11) patients free from diabetes, alcoholism and medication, influencing healing; (12) smoking-free patients. If individuals did not satisfy these criteria, they were excluded from the study.

Patients received a prophylactic dose of 2 g amoxicillin (Ospamox; Biochemie, Kiel, Germany) 1 h prior to the surgery. After the administration of 4% articaine 40 ml solution (Ubistesin; 3M ESPE, Germany) for local anesthesia, a mid-crestal incision on the center of edentulous ridge was performed. After crestal incision, buccal flap was raised, while lingual part was left not elevated to ensure direct visibility of the mucosa thickness. Vertical tissue thickness was measured with 1-mm marked periodontal probe (Hu-Friedy, Chicago, IL, USA) at the bone crest in the center of future implant position (Fig. 1a). The measurement was performed at two sites, where implants were planned to be placed. If soft tissue thickness was 2 mm or less at both sites, the study was continued. The place of probe touching the bone crest was gently marked with a pilot drill to mark exact seat of the implantation. After measurement, lingual flap was raised to completely expose the implant placement site. Then, sealed envelope was opened to select, which implant will be the first to insert. Subsequently, the implant of the other company was placed afterward.

The osteotomy site was measured to allow a minimum 3 mm distance between the two implants, 1.5 mm range from adjacent tooth/teeth and at least 1 mm space between buccal and lingual/palatal crest of the alveolar ridge and implant. Laser-microtextured collar implants without polished part (Tapered Internal Laser-Lok, Birmingham, AL, USA) with resorbable blast-textured (RBT) body were placed in one-stage approach crestally according to manufacturer's recommendations (Fig. 1b). Implants with platform switching and full acid-etched Osseotite surface (Certain Prevail; Biomet/3i, Palm Beach, FL, USA) were positioned in alveolar bone equally with bone level as well (Fig. 1c). In patients with missing both molars, implants were positioned adjacent to each other, while patients, who had missing second premolar and both molars, received implants in second premolar and second molar regions. After insertion, respective healing abutments were connected to both type implants, flaps

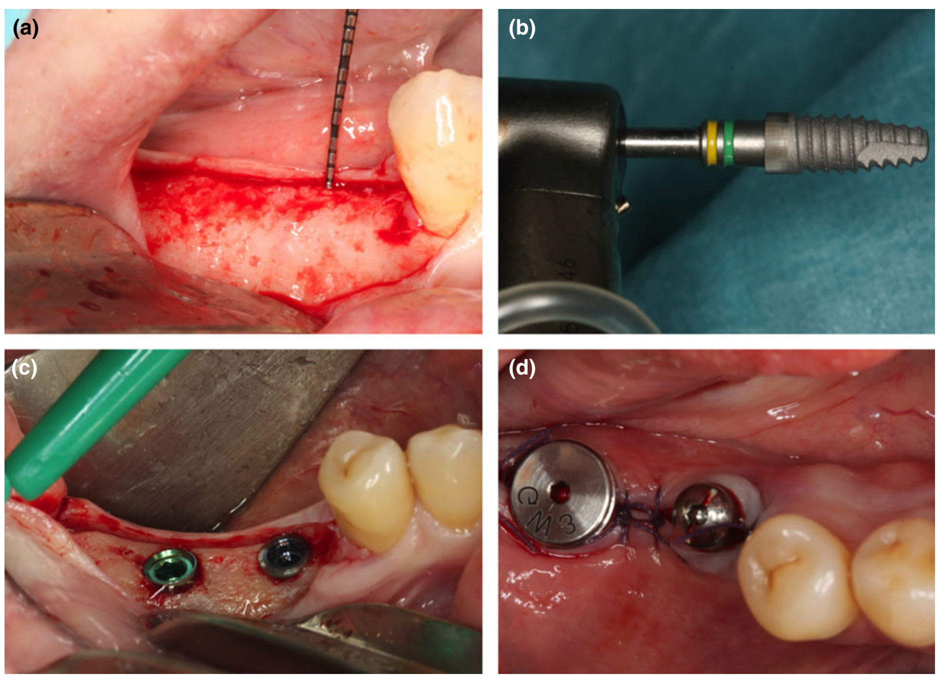

Fig. 1. (a) Thin mucosal biotype before implant placement, (b) BioHorizons Tapered Laser-Lok implant with laser-microgrooved neck to the top of the implant, (c) Position of both implants, (d) Healing abutments connected to implants during 1-stage surgery.

approximated and tissues sutured without tension with 5/0-interrupted sutures (Assucryl; Assut Medical Sarl, Lausanne, Switzerland) (Fig. 1d). Patients were instructed to rinse the operated site with 0.12% chlorhexidine-digluconate (Perio-aid; Dentaid, Barcelona, Spain) solution twice a day for a week and prescribed 0.5 g of amoxicillin (Ospamox; Biochemie) three times daily for 7 days. For pain control, patients were suggested 400 mg of ibuprofen to be taken as needed. Patients were advised to minimize trauma to the site and advised to clean healing abutments with very soft toothbrush. The sutures were removed 7–10 days after surgery.

Prosthetic treatment started 2 months after implant surgery. Open tray impression transfers, individual trays and vinyl-polysiloxane material (Variotime; Heraeus-Kulzer, Hannau, Germany) were used for impression making. Modified standard abutments were used as titanium bases for implant rehabilitation. Cement–screw metal–ceramic restorations were fabricated and delivered to implants. Before connection, restorations were decontaminated in 2% NaClO solution for 1 min and then neutralized in saline solution for 1 min. Implants were rinsed with 0.12% chlorhexidine-digluconate (Perio-aid; Dentaid), and 0.12% chlorhexidine-digluconate gel (Perio-aid gel; Dentaid) was applied before connection of the prosthesis. Occlusal opening of the restoration was isolated with sterile polytetrafluorine tape; veneering porcelain was etched with hydrofluoric acid and silanized. The access hole was covered with light-curing composite. During all prosthetic treatment, healing abutments were disconnected for three times and prosthetic treatment did not take more time than a month.

Intraoral radiographs were executed four times for each patient during the study: (1) after implant placement, (2) after 2 months of healing, (3) after prosthetic delivery and (4) after 1-year follow-up postreconstruction (Figs 2a,b and 3a–d). Paralleling technique of non-standardized X-rays with a Rinn-like film holder was used for radiographic examination. The images were obtained in the way that implant/abutment interface and the threads would be clearly visible. If necessary, the radiographs were taken again, till the implant–bone interface was clearly measurable. Radiological evaluation and measurements were performed using RVG Windows Trophy 7.0 software (Trophy Radiologie Inc., Paris, France) measurement program with a magnification (×20) by a blinded examiner. Before calculation of the crestal bone changes, the calibration of RVG images was performed with calibration program in

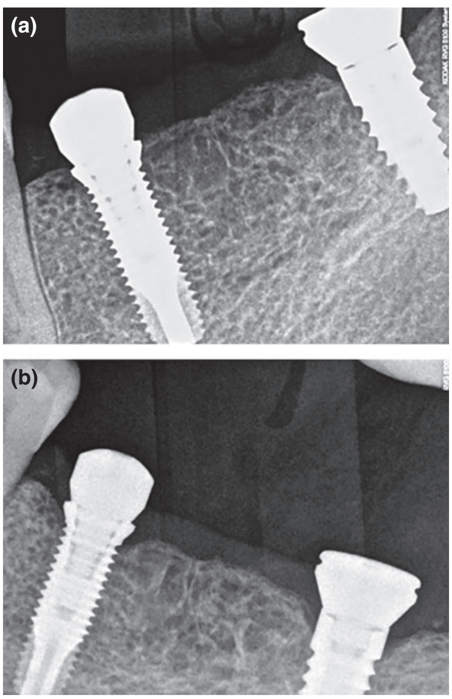

Fig. 2. Crestal bone levels around BioHorizons Laser-Lok and Biomet/3i implants (a) after placement and (b) 2 months of healing.

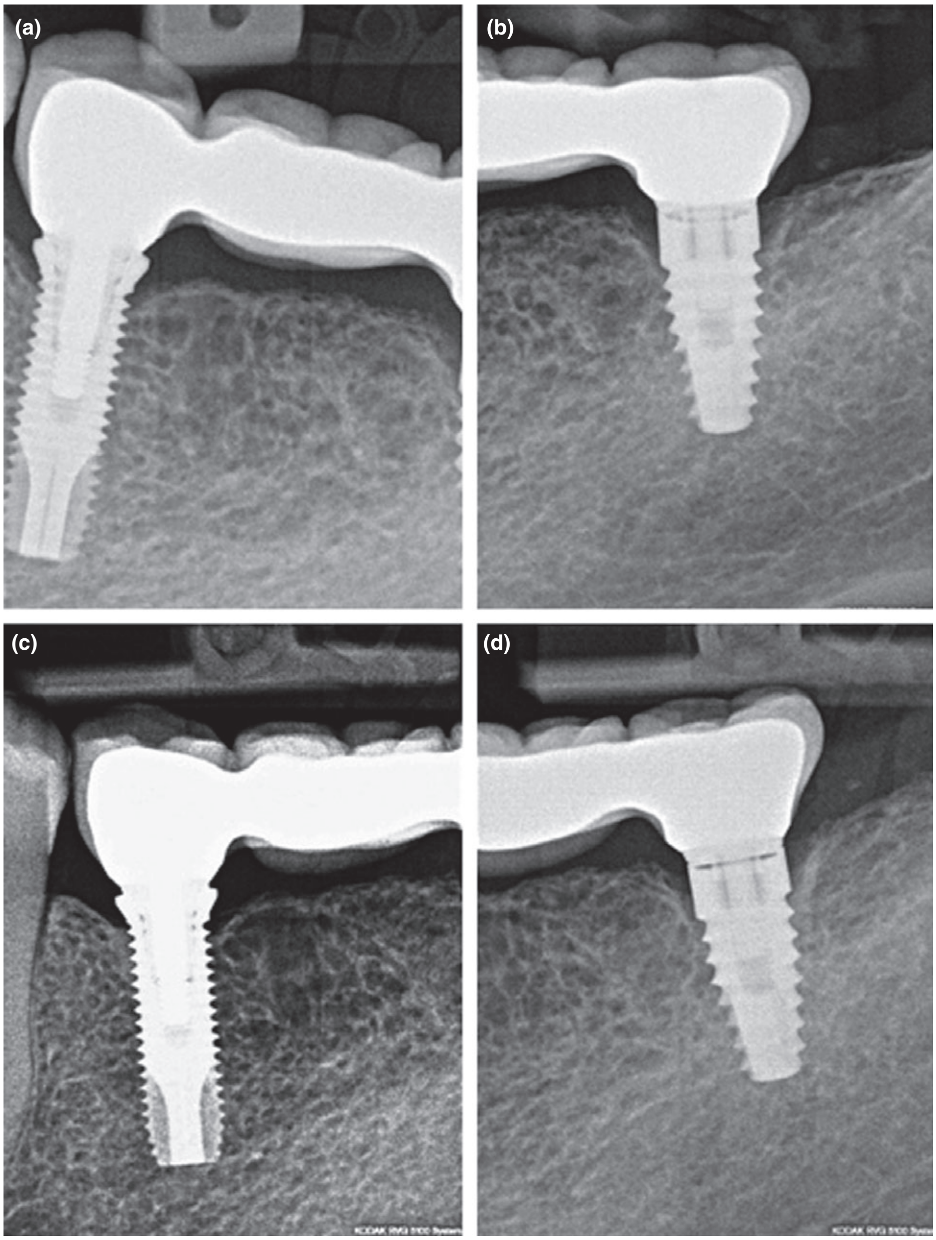

Fig. 3. Crestal bone loss around after restoration delivery (a) Biomet/3i implant, (b) BioHorizons Laser-Lok implant and after 1-year follow-up at (c) Biomet/3i, (d) BioHorizons Laser-Lok implants.

Trophy RVG software, using implant diameter as a reference point. Bone loss was calculated in millimeters by comparing baseline radiographs to radiographs obtained during recall visits. The edge of the implant and first radiographic bone–implant contact were selected as the reference points for bone loss calculation. The mean of the mesial and distal measurement was used for the implant. The second and the third measurements, which were performed with 1-month intervals, determined the intra-examiner agreement. The mean difference between measurements did not exceed 0.1 mm, and the mean of three measurements was used.

Data were analyzed using statistical software (SPSS 15.0 for Windows, Chicago, IL, USA), using patient as a statistical unit. Descriptive statistics, consisting of means, SEs, SDs, medians and range of the measurements, were calculated for crestal bone loss' and tissue thickness' values. The normality of the distribution was evaluated with a Kolmogorov–Smirnov test. As variables appeared to be nonparametric, Mann–Whitney *U*-test was adopted to find differences between the groups. The mean differences were considered statistically significant at $P \leq 0.05$ with a confidence interval of 95%.

Results

Patients were continuously screened until group of 30 individuals, satisfying inclusion criteria, was gathered. The final sample consisted of 12 males and 18 females with an average age 42.3 ± 2.4 ranging from 20 to 55 years at the beginning of the experiment.

Thirty 4.6 mm diameter implants with laser-microtextured collars (Tapered Laser-Lok, BioHorizons, Birmingham, AL, USA) and 30 implants with platform switching of 5/4 diameter (Certain Prevail; Biomet/3i) were placed, 12 implants in 2nd premolar region (seven BioHorizons, five Biomet/3i) and 48 in molar sites (23 BioHorizons, 25 Biomet/3i). Every patient received one pair of both implants. All 60 implants integrated successfully and were restored with 60 cement–screw-retained metal–ceramic restorations. Twelve patients were restored with 3-unit fixed partial dentures, while 18 patients received 2-unit splinted restorations. Overall, the implant survival rate after 1-year of function in both groups was 100%. No prosthetic complications were recorded at follow-up visits. Mean soft tissue thickness over BioHorizons implants was 1.76 ± 0.25 mm SD (range 1.50–2 mm, median 2) and 1.63 ± 0.43 mm SD (range 0.5–2 mm, median 1.75) over Biomet/3i; no statistically significant difference was registered ($P = 0.393$).

Crestal bone loss and statistical significance after 2 months, after prosthetic rehabilitation and after 1-year follow-up, are presented for both implant systems (Table 1; Figs 4 and 5). There was no statistically significant difference in crestal bone loss between 2-unit splinted restorations and 3-unit fixed partial dentures at 2 months ($P = 0.900$), after prosthetic reconstruction ($P = 0.202$) and 1-year follow-up after delivery of restorations ($P = 0.219$) (Table 2).

Discussion

The results of this study demonstrate that implants in Group 1 with laser-microtextured collar and platform-switched implants, which formed Group 2, were not able to maintain stable crestal bone level at the time of all measurements. This means that null hypothesis must be accepted. There was constant crestal bone loss, registered already 2 months after implant placement, continuing to increase during restorative treatment and reaching over 1.40 mm for both systems at 1-year follow-up. The outcome is in agreement with numerous studies, which indicate, that thin soft tissues can cause bone remodeling, during formation of biologic width around implants (Berglundh & Lindhe 1996; Linkevicius et al. 2009, 2010, 2013, 2014; Vandeweghe & De Bruyn 2012; Vervaeke et al. 2014; Puisys & Linkevicius 2013). It is known that almost 4 mm in height is required for protective soft tissue barrier that would form around implants, thus bone resorbs to create sufficient space for connective tissue adhesion (Tomasi et al. 2014).

However, it is interesting to note that implants showed different dynamics of bone resorption. Implants with platform switching developed significantly higher extent of bone remodeling after 2 months of placement,

Table 1. **Crestal bone loss measurement in both groups. Statistically significant difference between BioHorizons and 3i was recorded at the measurements after 2 months (*P* = 0.000) and after restoration (*P* = 0.001). After 1-year, no statistically significant difference was found (*P* = 0.976)**

	Mean (mm)	±SD	±SE	Min (mm)	Max (mm)	Median
Group 1 (BH)						
2 months	−0.71*	±0.25	±0.05	−0.25	−1.6	−0.65
Delivery	−1.10*	±0.30	±0.06	−0.65	−1.85	−1.08
1-year	−1.41	±0.42	±0.07	0.1	−2.30	−1.38
Group 2 (3i)						
2 months	−1.02*	±0.25	±0.04	−0.60	−1.55	−1.05
Delivery	−1.37*	±0.27	±0.04	−0.90	−1.80	−1.28
1-year	−1.43	±0.23	±0.05	−1.00	−1.80	−1.48

Mann–Whitney *U*-test, significant when $P \leq 0.05$.
BH, BioHorizons implants; 3i, Biomet/3i implants.
*Statistically significant difference.

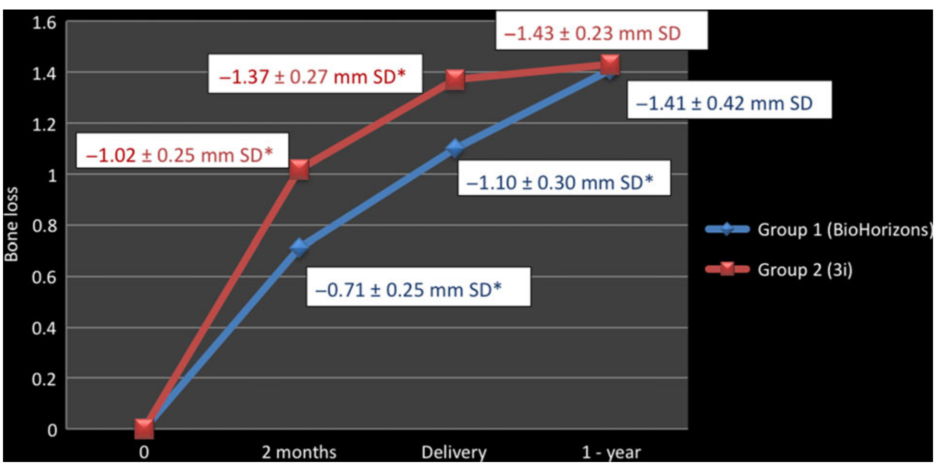

Fig. 4. Box plot representation of no statistical difference after 1-year follow-up ($P = 0.976$, Mann–Whitney *U*-test, significant when $P \leq 0.05$).
*Statistically significant difference.

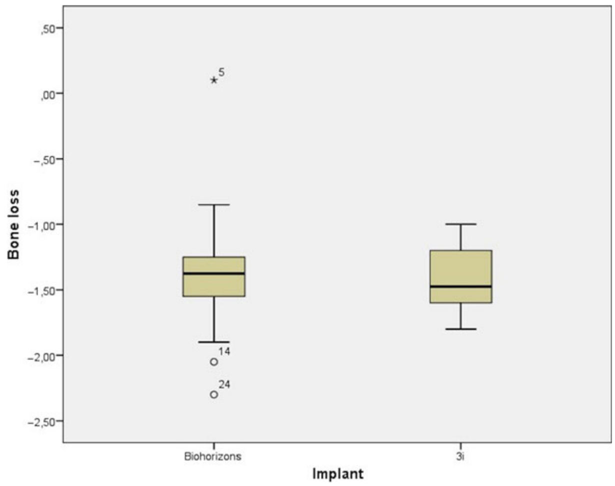

Fig. 5. Graphical representation of crestal bone loss dynamics around both implant systems. *Statistically significant difference.

***Table 2.* Crestal bone loss measurements in splinted restorations and 3-unit fixed partial dentures (FPD). No statistically significant difference at the measurements after 2 months (P = 0.900), after restoration (P = 0.202) and after 1 year (P = 0.219)**

	Mean (mm)	±SD	±SE	Min (mm)	Max (mm)	Median
Splinted (n = 12)						
2 months	−0.87	±0.30	±0.04	−0.25	−1.60	−0.80
Delivery	−1.26	±0.29	±0.04	−0.65	−1.85	−1.15
1-year	−1.46	±0.27	±0.04	−0.85	−2.30	−1.47
FPD (n = 18)						
2 months	−0.86	±0.28	±0.06	−0.50	−1.55	−0.82
Delivery	−1.17	±0.34	±0.07	−0.65	−1.80	−1.22
1-year	−1.33	±0.42	±0.09	0.1	−1.85	−1.30

Mann–Whitney U-test, significant when $P \leq 0.05$.

compared with laser-microtextured collar implants. The explanation may lay in the design of the implant/abutment connection of this implant. The body of the implant expands at the coronal aspect, resulting in the shift of collar diameter from 4 mm to 5 mm. This might result in a highly increased compression and trauma to mandibular alveolar bone, acting as a co-acting factor with thin soft tissues. It is well known that elasticity of maxillary bone is much higher, compared with mandible, thus more tolerant to extreme compression loads. It appears that this design in conjunction with thin mucosal tissue is not appropriate in keeping crestal bone stable, at least in mandibular posterior areas. The effect of platform switching in this implant actually results not from using abutment of the narrower diameter, but due to the expansion of implant body in coronal aspect, leaving the abutment the same diameter, as implant. In fact, manufacturer gives the number of 4.1 mm abutment diameter, which is even wider than that 4 mm implant body. The design of the mismatch and implant neck might be important, as it was reported that bone level implants with other design platform switching placed in thin tissues after 2 months had bone loss of lower extent equal to 0.76 mm (Puisys & Linkevicius 2013). Researches used the implant, which body and neck are parallel-walled without coronal extension, while abutment is 0.4 mm narrower, than implant body, thus no additional compression is shed on alveolar crest, when implant is inserted into osteotomy.

Conversely, laser-microtextured collar implants had significantly less amount of crestal bone loss after 2 months of healing and at restoration delivery moment, compared with platform-switched implants. Laser-grooving of the surface and implant neck without additional compression features seem to have better impact on bone stability during early phase of implant treatment in the population of this study. Another interesting observation was that a number of the laser-microtextured implants showed reduced crestal bone levels even in thin soft tissues, while platform-switched implants with expanded neck had more constant bone resorption, always exceeding 1 mm (Fig. 6a–d).

Manufacturer's recommendations dictated this implant to be placed equally with the crest, thus microgap had direct contact with the bone. Close proximity of the bone might explain gradual growth of bone resorption, therefore it may be suggested that better results should be achieved with slight supracrestal implant position.

However, in the broader picture, the results of the current study are not in agreement with trials, showing that microgrooved dental implants had bone loss of only 0.42 mm or 0.59 mm after 1-year follow-up (Pecora et al. 2009; Botos et al. 2011). There might be several reasons for this disparity. Botos et al. (2011) study had only 15 patients and that may not be sufficient to reflect general population. In addition, initial gingival tissue thickness was not measured in these studies; therefore, final conclusions might be limited. Recent study has shown that lack of soft tissue thickness registration in the beginning of the study, researching crestal bone loss, might result in distorted outcome (Linkevicius et al. 2014). Nevertheless, the concept of laser-microtexturing of the implant to promote better adhesion of the peri-implant tissues to implant and/or abutment is interesting and promising. This hypothesis was introduced by Nevins et al. (2008), claiming that controlled laser ablation technology creates microchannels on the surface and direct connective tissue attachment is developed. Iglhaut et al. (2013) have showed that the use of laser-microgrooved collar implant together with microgrooved healing abutment without disconnections resulted in the preservation of crestal bone levels and increased subepithelial connective tissue contact areas. This was a very interesting outcome, which could be tested in clinical studies. The positive reaction of laser-microtextured implant collar on crestal bone stability was shown in another clinical controlled trial, where bone loss around these implants was registered to be only 0.44 mm in thick soft tissue biotype and 0.32 mm in thin tissues thickened with acellular dermal matrix membrane during implant placement (Linkevicius et al. 2013).

Several limitations of the current experiment should be mentioned before drawing final conclusions. The results are restricted to the posterior mandibular area, and additional studies would be required to evaluate soft tissue thickness effect on crestal bone stability of platform-switched and laser-microtextured collar implants in the maxilla. Due to difference in bone elasticity and tissue thickness, we could expect different outcome. Another topic for discussion might be the measurement accuracy of the tissue thickness with calibrated periodontal probe.

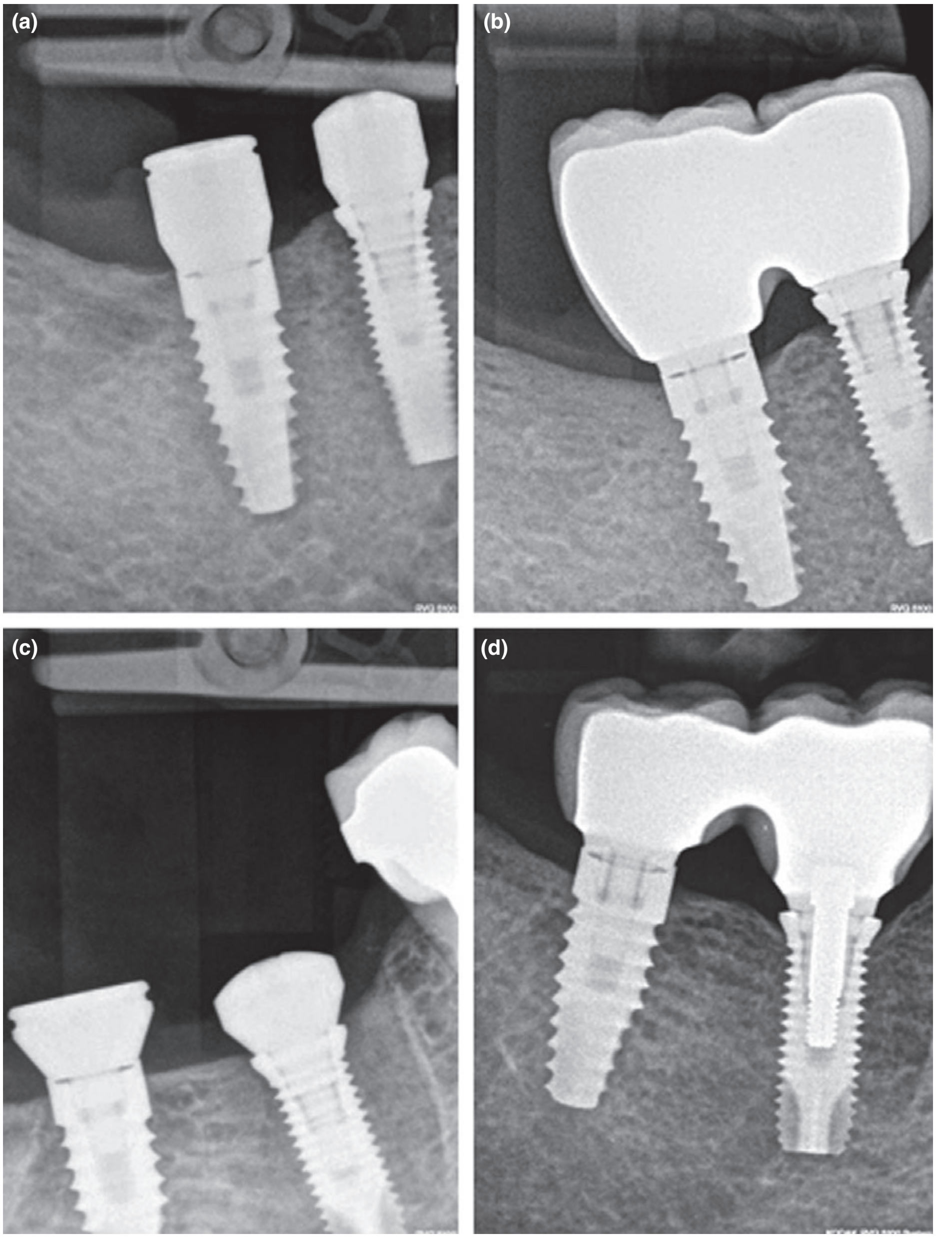

Fig. 6. Crestal bone level around BioHorizons and Biomet/3i implants in thin tissue biotype: (a, c) after placement, (b, d) 1-year follow-up. Note no bone loss around laser-microtextured neck implants.

The use of probe is completely accepted in measuring pocket depth in periodontology, thus it was decided to utilize it for direct measurement of vertical soft tissue thickness as well. In addition, many preceding studies successfully used this method of measurement (Linkevicius et al. 2009, 2010, 2013, 2014).

The use of two completely different implant systems does not allow a clear conclusion whether the observed differences in initial healing periods were due to the presence of Laser-Lok-modified implant neck in one of the groups. The compared implants besides differences in the neck design (laser microthreading or platform switch) have different surface macro- and possibly microtopography, design (tapered vs. parallel wall), surgical instrumentation and placement protocol as well as prosthetic components and prosthetic protocol. Therefore, further studies, comparing more similar design implants (for example, BioHorizons Tapered Laser-Lok implant vs. same design implant without Laser-Lok), could be conducted to answer the question more completely.

The restoration of the implants was carried out with splinted crowns or 3-unit fixed partial dentures. This could be considered as an additional limitation of the experiment, because implant loading conditions were not equal for all patients. Clinical situation urged that some patients needed second molars to be restored (chewing efficiency, support of opposing tooth or buccal tissues), therefore 3-unit fixed partial denture option was chosen to satisfy this demand. Loading of the implant in normal clinical conditions cannot be considered as a factor in crestal bone loss etiology, when the implant is already integrated. This is supported by numerous clinical data on implants with cantilevers, angled abutments or other increased loading situations showing no enlarged bone resorption (Sethi et al. 2000; Wennstrom et al. 2004; Halg et al. 2008). In addition, statistical analysis showed no significant differences in crestal bone loss between 2-unit splinted restorations and 3-unit fixed partial dentures.

And lastly, it should be mentioned that study used non-standardized X-rays, which might be significant source of bias for studies evaluating proximal bone levels. Although all efforts were made to reduce this bias by obtaining images in such a way that the implant–abutment interface and the threads would be clearly visible, it is considered that the projection geometry may differ between groups or different observation periods. It is know that peri-apical images are able to depict differences only at proximal sites, leaving unknown bone levels at labial and lingual regions.

Conclusions

Within the mentioned limitations of this study, it can be concluded that neither laser-microtexturing of implant collar or platform switching of implant/abutment connection did not maintain crestal bone loss, if at the time of implant placement, vertical soft tissue thickness was ≤2 mm. However, laser-microtextured Laser-Lok implants may present less proximal bone loss than 3i platform-switching implants in the period before implant loading in thin soft tissue biotype.

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