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Peri-implant soft and hard tissue condition after alveolar ridge preservation with beta-tricalcium phosphate/type I collagen in the maxillary esthetic zone: a 1-year follow-up study

Stanje tvrdog i mekog periimplantnog tkiva u estetskoj regiji gornje vilice posle prezervacije alveolarnog grebena beta-trikalcijum fosfatom sa kolagenom tip I: Studija sa jednogodišnjim periodom praćenja

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Abstract

Background/Aim. Alveolar ridge dimensional alterations following tooth extraction in the anterior maxilla often result in an inadequate bone volume for a correct implant placement. In order to obtain optimal bone volume various bone graft substitutes have become commercially available and widely used for socket grafting. The aim of this study was to examine and compare long-term clinical outcomes of dental implant therapy in the maxillary esthetic zone, after socket grafting with beta-tricalcium phosphate (TCP) combined with collagen type I, either with or without barrier membrane and flap surgery, after a 12-month follow-up. **Methods.** Twenty healthy patients were allocated to either C group (beta-TCP and type I collagen without mucoperiosteal flap coverage) or C+M group (beta-TCP and type I collagen barrier membrane with mucoperiosteal flap coverage). Following clinical parameters were assessed: implant stability (evaluated by a resonance frequency analysis – RFA), periimplant soft tissue stability (sulcus bleeding index – SBI, Mombelli sulcus bleeding index – MBI, periimplant sulcus depth, keratinized gingiva width, gingival level) and marginal bone level at the retroalveolar radiograms. **Results.** Within C+M group, RFA values significantly increased 12 weeks after implant installation compared to primary RFA values. Comparison between investigated groups showed a significantly reduced keratinized gingiva width in the C+M group compared to the C group after 3, 6, 9 and 12 months. Comparison between groups revealed significantly lower gingival level values in the C+M group at 9th and 12th month when compared to the C group. **Conclusion.** Implant treatment in the anterior maxilla could be effective when using a 9 months alveolar ridge preservation healing with combined treatment with beta-tricalcium phosphate and type I collagen, with regard to the peri-implant soft and hard tissue stability.

Key words:
dental implants; tooth extraction; bone substitutes; calcium phosphates; collagen; maxilla.

Apstrakt

Uvod/Cilj. Posle ekstrakcije zuba, dimenzionalne promene alveolarnog grebena u estetskoj regiji gornje vilice za posledicu često imaju nedovoljnu količinu kosti za ugradnju zubnih implanata. U vezi sa tim, primenjuju se različiti koštani zamenici sa ciljem očuvanja dimenzija alveolarnog grebena posle ekstrakcije zuba. Cilj rada bio je da se, posle prezervacije alveolarnog grebena beta-trikalcijum fosfatom (TCP) sa kolagenom tip 1, sa barijernom membranom i mukoperiostalnim režnjem i bez nje, ispitaju i uporede klinički ishodi zarastanja posle ugradnje zubnih implanata u estetskoj regiji gornje vilice, tokom jednogodišnjeg perioda praćenja. **Metode.** Dvadeset zdravih bolesnika podeljeno je u dve grupe: C (beta TCP/kolagen tip 1 bez barijerne membrane i mukoperiostalnog režnja) i C+M (beta TCP/kolagen tip 1 sa barijernom membranom i mukoperiostalnim režnjem). Praćeni su uobičajeni klinički parametri ishoda terapije: implantna stabilnost (analiza rezonantne frekvence), stanje mekih tkiva (indeks krvarenja, plak indeks, širina pripojne mukoze, recesija gingive) i nivo periimplantnog koštanog tkiva na retroalveolarnom radiogramu. **Rezultati.** U C+M grupi, implantna stabilnost posle 12 nedelja bila je značajno veća u odnosu na primarnu stabilnost. U C+M grupi, širina keratinizovane gingive bila je značajno manja posle 3, 6, 9 i 12 meseci u odnosu na C grupu. Recesija gingive bila je

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značajno veća u C+M grupi u odnosu na C grupu posle 9 i 12 meseci. **Zaključak.** Razmatrajući stabilnost mekog i tvrdog periimplantnog tkiva, terapija zubnim implantima može biti uspešna prilikom ugradnje u estetskoj regiji gornje vilice.

Ključne reči:
implanti, stomatološki; zub, ekstrakcija; kost, zamenici; kalcijum fosfati; kolagen; maksila.

Introduction

Single tooth replacement with an implant-supported restoration has become a viable treatment option in the maxillary esthetic region. However, alveolar ridge alterations after tooth extraction in the anterior maxilla often result in an inadequate bone volume. Buccal bone plate is usually resorbed during the first 8 weeks after tooth removal, leading to a predominantly horizontal alveolar ridge reduction in the following year [1–3]. In the systematic review, Tan et al. [4] reported the alveolar ridge reduction of 3.8 mm in width and 1.2 mm in height in the first 6 months after tooth removal. Mucosal changes after tooth extraction, consist of gaining thickness at the alveolar ridge crest, which increases by 0.4 mm after 4 months of healing. However, reduced bone volume, both vertically and horizontally, follows changes in the underlying alveolar bone [5, 6]. Although successful osseointegration of dental implants is highly predictable nowadays, a long-term outcome has been evaluated in view of the esthetic and functional stability. Taking into account long-term clinical results, it is well known that sufficient facial bone thickness is required to allow peri-implant soft and hard tissue stability and favorable esthetic outcome [7, 8].

To obtain an adequate bone volume after tooth extraction, different adjunctive procedures (alveolar ridge preservation, socket grafting, immediate implant placement) and different biomaterials (autografts, xenografts, synthetic biomaterials) have been proposed, resulting in less vertical and horizontal alveolar ridge alterations, which might prevent extensive bone augmentation techniques at later stages [9–14]. Despite the fact that autogenous bone grafts are considered as a *gold standard* due to viable bone cells and osteogenic potential, several limitations such as the presence of additional surgical site and morbidity, unpredictable graft resorption and limited bone volume may be disadvantages of this procedure [15–19]. Therefore, in order to obtain optimal bone volume in a minimally invasive manner, various bone graft substitutes have become commercially available and widely used for the alveolar ridge preservation. Bone graft substitutes may be used either alone or in combination with autogenous bone particles, and with or without barrier membrane coverage [14, 20, 21]. The use of barrier membranes prevents growing of fast proliferating fibrous tissue into a bony defect, which allows undisturbed bone regeneration, with fast clot formation and wound stabilization [22]. However, it has to be noted that exposure, infection or disintegration of the barrier membrane may lead to a failure of the grafting procedure [23]. Also, to obtain full barrier membrane coverage, esthetic outcome may be affected by mucoperiosteal flap elevation due to a reduction of keratinized gingiva in the grafted region. Data from experimental studies showed that the bone remodeling after tooth extraction is less pronounced after alveolar ridge preservation with flapless procedure [7]. On the other hand, in the study of Barone et al. [24], no histological and histomorphometric differences were observed 3 months after socket grafting with cortico-cancellous porcine bone covered with resorbable barrier membrane, comparing flapless and flap elevation procedures.

Beta-tricalcium phosphate (beta-TCP) is a bioactive bone substitute material with an osteoconductive and favorable resorptive properties [25], and the ability to support formation of new bone in grafted areas [26–28]. These properties were demonstrated even when beta-TCP was used without barrier membrane for grafting procedures during maxillary sinus floor augmentation or cyst removal in the mandible [29]. Beta-TCP may be successfully combined with collagen [30], although it was demonstrated that collagen alone is not capable of improving bone remodeling and counteracting post-extraction alveolar ridge alterations [31, 32]. Histologic, histomorphometric and immunohistochemical analyses showed that beta-TCP with type I collagen, either with or without barrier membrane and mucoperiosteal flap coverage, produced sufficient amounts of vital bone for consequent implant installation, with similar potential for bone healing during a 9-month observation period [20].

To our knowledge, there are no data reporting benefits of alveolar ridge preservation procedure on the long-term outcomes of implant treatment in the maxillary esthetic zone. Therefore, the aim of this study was to examine and compare long-term clinical results concerning quality of peri-implant tissue in the maxillary esthetic zone after alveolar ridge preservation with beta-TCP combined with type I collagen, either with or without barrier membrane and flap surgery.

Methods

Study sample and design

Ethics approval was obtained from the Ethics Committee of the Faculty of Dental Medicine, University of Belgrade (No. 36/21) and all participants signed the informed written consent. Study registration was performed at ClinicalTrials.gov (NCT02507661) and study has been conducted in accordance with the ethical standards laid down in 1964 Declaration of Helsinki and its later amendments. This randomized study included 20 adult participants of both genders, aged between 18 and 65 years, referred to the Oral Surgery Clinic for single maxillary tooth extraction and post-extraction alveolar ridge preservation, prior to dental implant placement.

Inclusion criteria were: healthy patients (ASA I physical status) with single maxillary tooth in the maxillary esthetic zone (incisors, canines or premolars) indicated for extraction due to a root fracture, unsuccessful endodontic treatment or chronic periodontal disease, and with at least 6 mm of remaining alveolar height; extraction sockets with four intact bony walls and thick, medium and thin gingival biotype; adequate occlusion for the proposed prosthodontic treatment. Patients were excluded in cases of: heavy smoking, acute periodontal disease with severe bone loss, chronic orofacial pain, pregnancy and lactation, and alcohol and/or drug abuse.

Study procedure

All extractions were performed under local maxillary infiltration anesthesia (2 mL of 4% articaine with epinephrine 1:100.000) in a minimally traumatic manner. After a tooth extraction, an alveolar socket debridement was done and single beta-TCP cone with type I collagen (RTR Cone®, Septodont, France) was placed into the socket to completely fill the space. Participants were randomly assigned to one of the following two groups: group C (beta-TCP + type I collagen) – 11 participants with cones placed into the extraction socket without barrier membrane and mucoperiosteal flap coverage; group C+M (beta-TCP + type I collagen with membrane) – 9 participants with cones placed into the extraction socket and covered with barrier membrane (Bio-Gide®, Geistlich AG, Switzerland) and mucoperiosteal flap.

In the C+M group, full thickness mucoperiosteal flap was elevated, following two vertical and horizontal intrasulcular incisions. Periosteal incision was performed to obtain necessary flap mobility for the cone and barrier membrane complete coverage, followed by interrupted sutures.

Postoperatively, participants were instructed to take amoxicillin (Sinacilin® 500 mg, Galenika, Serbia), 3 times daily for 7 days and ibuprofen (Brufen® 400 mg, Galenika, Serbia) as necessary, as well as to follow the postoperative protocol (antiseptic mouth wash twice daily for ten days and soft diet). Participants attended regular check-ups at 3rd, 5th and 7th day. Sutures were removed after 7 days.

Fig. 1 – Periapical radiograph with screw-retained temporary crown.

Dental implants (AstraTechOsseoSpeed TX®, Dentsply Implants, Sweden) were installed 9 months after the socket preservation according to the delayed implant placement protocol, followed by temporary crown for first 2 months (Figure 1) and screw-retained final metalo-ceramic crown delivery (after 2 months of temporary crown).

Clinical parameters

Clinical parameters evaluated during the follow-up period were: implant stability, peri-implant soft tissue stability and peri-implant bone level changes.

Implant stability was evaluated by means of resonance frequency analysis (RFA) using OstellMentor® appliance (Integration Diagnostics, Sweden). The transducer from the appliance set was perpendicularly positioned into the implant body (Figure 2) and measurements were repeated until two identical RFA values were obtained, which was considered as a value of implant stability. Measurements were performed immediately after implant placement and after 3, 6, 8 and 12 weeks postoperatively.

Fig. 2 – Implant stability measurement with OstellMentor® appliance.

Peri-implant soft tissue stability was assessed according to a Mombelli sulcus bleeding index (SBI), Mombelli modified plaque index (MPI) and with following gingival parameters: peri-implant sulcus depth, keratinized mucosa width and gingival level. SBI and MBI were measured at the mesial, distal, buccal and palatal aspect of each implant [33]. Peri-implant sulcus depth was evaluated at the same four sites *per* implant. Measurements were performed at the midfacial aspect of the implant as the distance between the most coronal gingival margin and the sulcular depth. Keratinized gingiva width was measured at the midfacial aspect of the implant as the distance between midfacial gingival margin and mucogingival junction. Gingival level was measured at the midfacial position of buccal mucosa as the distance of marginal gingiva and mucogingival junction, registering the level of gingival recession. Measurements were performed 2, 3, 6, 9 and 12 months after the implant placement using manual periodontal probe.

Peri-implant bone level changes were measured on periapical radiographs, taken with parallel technique immediately after implant placement (Figure 3), as well as after 3, 6, 9 and 12 months. The marginal bone level was regarded as the distance between the implant-abutment connection and the first bone-to-implant contact. All measurements were performed at the mesial and distal aspects of each implant in the specialized image software (ImageJ, National Institute of Health, USA).

Fig. 3 – Periapical radiograph immediately after implant placement.

Statistical analysis

Statistical analysis was performed in SPSS v.20. Demographic data were analyzed by means of descriptive statistics, χ^2 and Man Whitney *U* test. Clinical parameters were compared between groups using Mann Whitney *U* test, while the changes within investigated groups during follow-up period were analyzed by Friedman test with Wilcoxon Sign Rank post hoc. The level of statistical significance was set at 0.05.

Results

Characteristics of the study population are presented in Table 1. There were no statistically significant differences between the investigated groups regarding age, smoking habits, dental diagnosis as well as implant distribution according to dimensions.

Implant stability analysis revealed that there were no significant differences in RFA values within the C group, during the observation period. Within the C+M group, RFA values significantly increased 12 weeks after implant installation in comparison with primary stability values (Table 2). Comparison between investigated groups did not show significant differences in RFA values during the observation period (Table 2).

Table 1

Demographic and surgical data of the study population

Parameters	Group C	Group C+M
Patients, n	11	9
Age (years), mean ± SD	49 ± 15	46 ± 13
M/F (n)	5/6	3/6
Smoker/non smoker, n	4/7	5/6
Diagnosis, n		
A/B/C/D	2/6/2/1	2/3/1/3
Implants, n		
$3.5^a \times 11^b$	5	5
$4.0^a \times 11^b$	6	4

Group C – beta-tricalcium phosphate (TCP) and type I collagen without mucoperiosteal flap coverage;

Group C+M – beta-TCP and type I collagen barrier membrane with mucoperiosteal flap coveage;

M – males; F – females; A – periodontal disease; B – non-vital tooth; C – chronic periapical lesion; D – tooth fracture; n – number of patients; SD – standard deviation

[a] –implant diameter in mm; [b] – implant lenght in mm.

Table 2

Resonance fraquency analysis values during the observation period

Weeks	Group C* (mean ± SD)	Group C+M* (mean ± SD)	p^a
0	69.6 ± 6.2	69.4 ± 5.9	n.s.
3	66.4 ± 4.9	66.6 ± 5.7	n.s.
6	68.1 ± 4.9	71.3 ± 4.6	n.s.
8	70.5 ± 5.2	73.9 ± 4.5	n.s.
12	74.3 ± 6.4	76.4 ± 5.4*	n.s.
p^b	0.11	0.01	

***Explanation see under Table 1.**

SD – standard deviation; [a]Mann-Whitney test; [b]Friedman test; $^*p < 0.05$ – 0 vs. 12th week (Wilcoxon Sign Rank *post hoc*).

Values of bleeding and plaque indices did not change significantly during the observation period except between the C and C+M groups concerning the Mombelli plaque index, 3 months after implant placement (Table 3).

Keratinized gingiva width was not significantly changed within investigated groups during the 12-month period of observation (Table 4). However, comparison between the investigated groups showed a significantly reduced keratinized gingiva width in the C+M group starting from the 3rd month, compared to the C group (Table 4).

Table 3

Values of bleeding and plaque indices (Mombelli) during the observation period

Month	Bleeding index			Plaque index		
	Group C* (mean ± SD)	Group C+M* (mean ± SD)	p^a	Group C (mean ± SD)	Group C+M (mean ± SD)	p^a
2	0.10 ± 0.31	0.13 ± 0.35	n.s.	0.20 ± 0.63	0.38 ± 0.74	n.s.
3	0.40 ± 0.52	0.48 ± 0.52	n.s.	0.25 ± 0.53	0.50 ± 0.46	< 0.05
6	0.20 ± 0.32	0.33 ± 0.54	n.s.	0.30 ± 0.68	0.50 ± 0.76	n.s.
9	0.60 ± 0.52	0.63 ± 0.52	n.s.	0.20 ± 0.42	0.38 ± 0.52	n.s.
12	0.40 ± 0.52	0.25 ± 0.36	n.s.	0.20 ± 0.42	0.25 ± 0.46	n.s.
p^b	n.s.	n.s.	n.s.	n.s.	n.s.	

***Explanation see under Table 1.**

SD – standard deviation; [a]Mann-Whitney test; [b]Friedman test; Wilcoxon Sign Rank *post hoc*.

Table 4

Peri-implant soft tissue parameters during the observation period

Months	Keratinized gingiva			Peri-implant sulcus depth			Gingival level		
	Group C[1]	Group C+M[1]	p^a	Group C	Group C+M	p^a	Group C	Group C+M	p^a
2	3.6 ± 1.0	3.0 ± 1.1	n.s.	2.40 ± 0.71	1.80 ± 0.63	n.s.	2.37 ± 0.42	1.98 ± 0.68	n.s.
3	3.8 ± 0.9	2.9 ± 0.7	0.047	2.40 ± 0.84	2.00 ± 1.11	n.s.	2.41 ± 0.42	1.95 ± 0.57	n.s.
6	3.9 ± 1.0	2.8 ± 0.8	0.035	2.31 ± 0.97	2.20 ± 1.07	n.s.	2.33 ± 0.70	1.76 ± 0.41	n.s.
9	3.7 ± 0.9	2.7 ± 0.8	0.013	2.88 ± 0.68	2.29 ± 0.35	0.03	1.88 ± 0.66	1.29 ± 0.35	0.04
12	3.7 ± 0.9	2.7 ± 0.9	0.011	2.85 ± 0.65	2.20 ± 0.21	0.04	1.86 ± 0.69	1.18 ± 0.21	0.04
p^b	n.s.	n.s.		0.032	0.048		n.s.	0.035	

Values given as mean ± standard deviation in mm.
[1]Explanation see under Table 1.
[a]Mann-Whitney test; [b]Friedman test; Wilcoxon Sign Rank *post hoc*.

Comparing peri-implant sulcus depth within C and C+M groups, there was a significant increase of sulcus depth after 12 months in comparison with the 2nd month (Table 4). Significant differences regarding this parameter between investigated groups were also obtained after 9 and 12 months (Table 4).

Gingival level was significantly reduced in the C+M group after 9 and 12 months of observation (Table 4). There were no significant differences in gingival level in the C group. Between groups comparison revealed significantly lower gingival level values in the C+M group at the 9th and 12th month when compared to the C group (Table 4).

Peri-implant bone levels did not change significantly during a 12-month observation period, neither within nor between the investigated groups (Table 5).

Table 5

Radiographic evaluation of the peri-implant bone level

Months	Group C* (mm) mean ± SD		Group C+M* (mm) mean ± SD		p^a
	mesial	distal	mesial	distal	
2	0.7 ± 0.7	0.6 ± 1.2	0.8 ± 0.7	0.9 ± 0.9	n.s.
6	0.9 ± 0.7	1.2 ± 1.1	1.3 ± 0.9	1.4 ± 1.1	n.s.
9	1.0 ± 0.5	1.2 ± 1.0	1.1 ± 0.6	1.1 ± 0.4	n.s.
12	1.3 ± 0.7	1.6 ± 1.0	1.4 ± 0.6	1.8 ± 0.2	n.s.
p^b	n.s.	n.s.	n.s.	n.s.	

***Explanation see under Table 1.**
[a]Mann-Whitney test (comparison between groups for mesial and distal side);
[b]Friedman test, Wilcoxon Sign Rank *post hoc*.

Discussion

RFA values obtained in our study imply high levels of primary and secondary implant stability in both investigated groups for 12 weeks observation period (> 65 implant stability quotient – ISQ). It should be noticed that implants were placed in the solid, mostly mineralized alveolar bone, 9 months after preservation, where implant micro-movements, evident after immediate placement, were not present. Expected decrease in implant stability was observed after 3 weeks in both groups because of bone healing and remodeling processes, but transition from primary stability as a mechanical phenomenon to secondary stability as biological type of bone-to-implant connection [34] was evident. In the C+M group significant increase in RFA values (and implant stability) was observed at 12 weeks in comparison with primary stability values, while in the C group significant changes were not observed. This difference may be explained with a pattern of bone healing in non-membrane group, which is characterized by thin immature trabecular bone in cervical and central part of the post-extracting preserved socket [20].

Marginal bone remodeling occurred in both investigated groups, with similar values between groups at the mesial and distal implant sides during the observation period of 12 months. Slightly higher values of 1.9 mm were observed in the C+M group compared to 1.6 mm in the C group at the end of the observation period, but differences were not significant. The first progressive bone loss in our study occurred during first 6 months after the implant placement, 1.2 mm at the distal side in the C group and 1.4 mm at the distal side in the C+M group. These results are in agreement with the study of Cochran et al. [35], who reported that the most pronounced peri-implant bone remodeling occurs during first 6 months after one-stage protocol implant installation, although reported mean values in the study were 2.44 mm. This reduction is probably a result of early bone remodeling during the first year with implant osteotomy preparation, interruption of vascular supply and possible inflammation [35]. In the study of Hartman and Cochran [36], after using the same one stage protocol, the most bone loss also occurred during first 6 months after implant installation, with average bone loss of 1.10 mm. The authors concluded that the early bone loss directly depends on the implant design and three-dimensional implant position. Concerning that, it is explained that this process depends on various factors, including type of implant-abutment connection, as well as implant neck surface characteristics [37–40]. It seems that tapper connection of implants used in this study, with internal hexagon, allows horizontal displacement of implant-abutment interface. It is reported that this type of connection leads to the lesser apical migration of biological width, since micro-movements and stress transmission occur at a distance from the marginal bone, which is followed by less marginal bone resorption [41–43].

The important part of analysis was the peri-implant soft tissue stability. The midfacial soft tissue level (gingival level) significantly decreased in the C+M group after 9 and 12 months in comparison with the C group. Furthermore, the gingival recession in the C+M group at mentioned time points was significantly lower in comparison with baseline measurement. The observed pattern of the midfacial soft tissue recession is possibly a result of restoring adequate biological dimensions of the tissue; it seems to be present during early healing phase irrespectively of implant treatment modality, especially when flap surgery was done. Similar values were obtained in studies with single-tooth implants installation with standard surgical approach [44], as well as after single-tooth implants installed with bone augmentation procedure [45].

Most clinical studies reported that the amount of gingival recession significantly increased at the implant sites with reduced keratinized mucosa [46–48]. This is in accordance with our results of keratinized mucosa level and gingival recession in the C+M group, pointing that the deficient keratinized mucosa is related with the increased gingival recession. Furthermore, buccal probing depth showed a tendency to be slightly higher in the sufficient keratinized mucosa, while plaque and bleeding index were higher when keratinized mucosa was deficient, what is in accordance with previously published data [46–48].

From a clinical point of view, stability of peri-implant crestal bone level is crucial for a long-time implant outcome in the maxillary esthetic zone. Namely, an appropriate amount of keratinized mucosa prevents mucosal traction during masticatory function, which is a positive influence of a wide keratinized mucosa of 2 mm on a crestal bone level. Regarding the proper width of keratinized mucosa, the better results of the C group could be explained with higher tissue stability and lower biofilm accumulation. Conversely, sites with deficient keratinized mucosa have a potential difficulty in maintaining adequate health of peri-implant tissue [49]. Additionally, keratinized mucosa in the vicinity of implants probably reduces inflammatory alterations of connective tissue, which is in accordance with other studies [50].

Conclusion

This clinical study showed that treatment of the maxillary esthetic zone could be effective using 9 months alveolar ridge preservation healing combination of beta-tricalcium phosphate and type I collagen in a term of the peri-implant soft and hard tissue stability. Marginal mucosa stability strongly affects the esthetic outcomes in the restored maxillary esthetic zone if gingival recession occurs. Further data on the long-term survival and success rates of dental implants are needed.

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