Preservation of alveolar ridge using beta-tricalcium phosphate and collagen type I (RTR Cone®) prior to implant placement: clinical, histological and histomorphometrical observations

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Introduction

Following tooth extraction, blood clot develops inside the socket walls and finally leads to new bone formation. However, this healing process never allows complete restitution of initial volume of alveolar ridge due to well-known physiological bone resorption. These resorption process varies amongst individual patients and tooth position, and may be additionally affected by presence of local infection sites, periodontal disease, alveolar bone fenestrations as well as thickness of the alveolar socket buccal bone walls (Garg et al. 2001).

Healing process of bone tissue after tooth extraction results in dimensional changes of residual alveolar ridge in both dimensions, horizontal dimension with modification of alveolar bone width, and vertical dimension which affects the height of alveolar bone. These tissue changes have been reported as leading 40-60% decrease in the both dimensions (Farmer and Darby 2014), with significant reduction in the first 3 months after tooth extraction resulting in bone and soft tissue level that is lower than that of adjacent teeth, what was predominantly seen

after multiple adjacent extractions (MacBeth et al. 2016, Chen et al 2004). Regarding the soft tissue remodeling after tooth extraction, the volumetric reduction and subsequent soft tissue contour change have been occurred, narrowing of the keratinized mucosa and attached gingiva (Schneider et al. 2014, Thoma et al. 2009).
To reduce the loss of alveolar bone and soft tissue to an acceptable level, the preservation of alveolar ridge has been proposed. These may include minimal traumatic extraction, followed by immediate grafting of the extraction sites using biomaterials, without the use of barrier membranes, if integrity of the socket 4-walls is presented (Brkovic et al. 2008). In addition to the function of biomaterials that replace the missing portion of alveolar bone, space provision and blood clot stabilization inside the biomaterials, offer osteoconductive and, later, osteoiductive properties of biomaterials (Aybar et al. 2004, Zerbo et al. 2001).
Beta-tricalcium phosphate (ßTCP) is alloplastic, biocompatible, synthetic material produced by Septodont, France, indicated in different clinical cases in oral surgery, periodontal surgery and implantology, used in 2 forms, particulate (R.T.R. Syringe® - plain ßTCP) or conical form (R.T.R. Cone® - ßTCP + Type I collagen). It has been documented the use of ßTCP for the preservation of alveolar ridge immediately after tooth extraction, prior to implant placement, in the combined form of ßTCP and Type I collagen (Brkovic et al. 2012).

Case report with surgical considerations

Healthy patient who required tooth extraction was evaluated for post-extraction socket preservation prior to dental implant placement in the frontal part of upper jaw.
After minimal invasive extraction of #13 was performed under local anesthesia, clinical examination was done to detect a socket 4-walls integrity, to clean debris of post-extraction sites and to remove chronical granulation tissue peri-radicular ***(Fig. 1)***. A single R.T.R. Cone® containing beta-tricalcium phosphate with type I collagen (ßTCP/Clg) (Septodont, Saint-Maur-des-Fosses, France) was placed into the internal socket space ***(Fig. 2)***. To obtained as a larger area of bone/material contact, ßTCP/Clg cone was trimmed to the more conical form to completely occupy the space from the marginal edge of alveolus to the apex of the socket. Regarding that, trimmed particles of ßTCP/Clg were firstly inserted into the narrow apical part of socket, while the rest of socket space, middle and cervical part, was filled with trimmed solid conical form. After cone placement, the alloplastic material and socket opening was left to heal spontaneously without the use of barrier membrane or a mucoperiosteal flap ***(Fig. 3)***. In case of multiple adjacent teeth extractions, interrupted sutures can be positioned at the level of mesial and distal papillae.
A 7-day course of amoxicillin 500 mg per oral and pain control medication as required were prescribed and detailed

Fig. 1: Extraction socket with 4-walls prepared for filling with betaTCP/Clg (taken from Brkovic et al. Clin Oral Invest 2012,16:581-590).

Fig. 2: betaTCP type 1 collagen cone placed into socket (taken from Brkovic et al. Clin Oral Invest 2012,16:581-590).

Fig. 3: betaTCP type 1 collagen cone trimmed to fit snugly into socket with blood clot inside the material (taken from Brkovic et al. Clin Oral Invest 2012,16:581-590).

postoperative instructions were given to patient. The control of soft tissue healing was done at days 3 and 7, and then at 4 and 9 months after the preservation for clinical control of bone and soft tissue healing associated with the radiographic evidence *(Fig. 4, 5)*.

Fig. 4: Healing of mucosa around non-membrane betaTCP type 1 collagen filled socket, 1 week following placement (taken from Brkovic et al. Clin Oral Invest 2012,16:581-590).

Fig. 5: Alveolar ridge exposed at biopsy and implant placement 9 months following socket preservation with betaTCP type 1 collagen without a barrier membrane (taken from Brkovic et al. Clin Oral Invest 2012,16:581-590).

Results

The presented results of clinical and histological outcomes after 9 months of healing were published in Clin Oral Invest 2012, 16:581- 590, while results of 4 months of healing were presented at EAO 2016.

Clinical outcomes

Clinical results were evaluated after 4 and 9 months of healing. There was no significant difference between observed times in the vertical and horizontal dimensional changes *(Table 1)*, while characteristics of grafted area at the time of implant placement were different *(Table 2)*. Four months healing period was determined with less drilling and bone-like resistance, mostly flexible with significant evident of particles inside the treated sites. All treated sites healed uneventfully with completed gingiva closure of socket opening in 2 weeks, in both observation times.

Table 1: Changes of alveolar ridge dimension (mm)

Characteristics	9 months of healing	4 months of healing	P
Horizontal dimension	6.59 ± 2.44	5.13 ± 2.89	NS
Vertical dimension / buccal aspect	3.60 ± 1.51	3.10 ± 2.18	NS

Table 2: Time for complete epithelization of socket opening and clinical characteristics of grafted area at the time of implant placement (mean ± SD)

Characteristics	9 months of healing	4 months of healing	P
Epithelial closure of socket opening (day)	19.1 ± 4.7	20.3± 6.7	NS
Visibility of particles (yes/no)	4/7	9/1	p=0.03
Continuity with native bone(yes/no)	11/0	5/5	NS
Fibrous adhesions (yes/no)	2/9	4/7	NS
Purulent discharge(yes/no)	0/11	0/11	NS
Drilling resistance (bone quality)			
Decreased resistance	4	7	NS
Bone-like resistance	7	3	NS
Probing resistance			
Hard	6	3	NS
Flexible	4	5	NS
Soft	1	2	NS
Reduction of attached gingiva (yes/no)	0/11	0/10	NS
Reduction of attached gingiva (yes/no)	0/11	0/10	NS

Histology

Both healing periods, 4 and 9 months, have shown mineralized trabecular bone type characterized by a presence of woven in comparison with lamellar bone in 4 months of healing, while immature lamellar bone was evident in 9 months period predominantly in aplical and peripheral parts of bone samples ***(Fig. 6, 7)***. Trabecular bone was lined with active osteoblast and osteoblast-liked cells with all characteristics of new bone formation (irregularity in shape and position of lacunas, osteocysts as a sign of vitality, reversal lines as a sign of different dynamic in bone formation and maturity) ***(Fig. 8)***. Particulate non-resorbable granules of ßTCP were very well incorporated inside the new bone formation without inflammatory cell infiltration and fibrous tissue reaction ***(Fig. 9)***.

Histomorphometric outcomes

Histomorphometric analysis has shown significant difference in new bone formation and marrow bone between 4 and 9 months of healing with more bone occupied sites that healed longer. More, but not significant, reduction of residual graft was recorded after 9 months of healing in comparison with 4 months of healing. Fibrous tissue was mostly evident in earlier phase of healing of 4 months than after 9 months of healing (Table 3).

Table 3: Histomorphometric results (%)

Characteristics	9 months of healing	4 months of healing	P
New bone	42.4 ± 14.6	30.8 ± 7.2	.05
Marrow	42.7 ± 10.9	24.3 ± 11.4	.05
Residual graft	9.7 ± 7.3	18.5 ± 9.0	NS
Fibrous tissue	4.4 ± 3.6	26.4 ± 4.8	.05

Discussion

Results of the study demonstrate that betaTCP/Clg provides an effective bone regenerative network which can allow in-growth of active cellular and vascular components inside the material. This characteristic of osseoconductive material will enable a formation of new mineralized bone and bone marrow in a human extraction socket after using betaTCP/Clg for preservation of alveolar ridge. Histological evidence which was presented with newly formed bone, lined with osteoblast and osteoblast-liked cells, demonstrated that active bone formation was still in process 4 and 9 months after preservation. Furthermore, the evidence that active osteoblasts produce osteoid, as first evidence of bone tissue, taking places not only around new bone but also inside the material porosity system, resulted finally with the appearance of new centers of ossification. The biological contribution of calcium ions and collagen type I improves induction potential of grafted sites to surrounded vital bone for cells migration and growth factor penetration supporting osteoblastic differentiation and proliferation resulted in acceleration of the healing process in bone defects (Pioletti DP et al. 2000, Barrere et al. 2006). Next, the well incorporated particles of betaTCP inside the new bone confirm biocompatibility and activity of ossification (Thompson et al. 2006).

The alveolar crestal bone level did not change significantly over the time of bone healing in 4 and 9 months in both directions, vertical and horizontal. On the other hand, the expected resorption of the alveolar bone during the physiological healing of extraction sockets is usually seen with the significant changes in the first 3 months after the extraction (Chen et al 2004). That way, preservation of alveolar ridge after tooth extraction and prior to implant placement might be clinically relevant option having in mind stability of post-extraction sites and prevention of its resorption. Another important thing is that a mucoperiosteal flap and barrier membrane for guided bone regeneration have not played any crucial rule in case with all four-wall socket preservation what was also documented by Herberer et al using BioOss + Collagen in the same model of human socket preservation. There are several possible mechanisms to explain the blockade of fibrous tissue in-growth into the porous material structure of the ß-TCP granules. Metabolites and a local decrease in pH during the material dissolution can inhibit the fibroblastic proliferation, while afterward that process will be intensive by a strong connection of material and bone through the ion's reaction (Pioletti et al. 2000, Zerbo et al 2005).

Preservation of alveolar ridge have been recorded as changing the structural and histological characteristics of the bone and gingival tissue with the goal for promoting the establishment of an adequate functional, biological and aesthetic foundation before implant supported prosthodontics. If alveolar bone walls are still preserved, they can provide blood supply as well as mechanical support for the placement of a bone-filling material in the resorption site and maintain the initial volume of bone (Cortellini and Tonetti 2015). Additionally, clinical results of soft tissue stability indirectly demonstrated positive influence of preservation method on the design of the final implant supported crowns improving the emergence profile of the restoration with increase in the gingival papilla height and expression of the fixed keratinized tissue dimensions (Belser et al. 2004).

Regarding the results of this clinical study, it can be concluded that the combination of betaTCP/Clg can prevent the reduction of original dimension of the alveolar bone when used for the preservation of four-wall extraction socket without the barrier membrane and surgical flap used. The active bone formation ensured the quality of regeneration important for successful implant osseointegration suggesting both 4 and 9 months of healing as a relevant from the point of safe and successful implant placement.

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