Bone grafting using an in situ hardening synthetic material with simultaneous early implant placement

Simplified protocol, successful results

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This case report highlights the use of a novel in situ hardening synthetic resorbable bone substitute composed of beta tri-calcium phosphate (β-TCP) and calcium sulfate (CS) for alveolar bone augmentation in parallel to early implant placement. The biological and biomechanical properties of the grafting material helped promoting the regeneration of newly-formed vital bone, while allowing for simplified, minimally invasive surgical techniques.

Introduction

Early implant placement is performed two to eight weeks after tooth extraction and is usually combined with simultaneous bone augmentation in an attempt to rebuild and maintain the architecture of the hard and soft tissues of the alveolar ridge [1]. According to the existing knowledge this technique overcomes the main disadvantages of immediate implant placement, like the enhanced risk of infection and the lack of soft tissue closure, while the short-term survival rate of implants seems to be similar between immediate, early and late approaches [2-6].

In early implant placement, as the implant is placed into an extraction socket, a gap of variable distances will be present between the implant surface and the surrounding bone walls. Moreover, it is possible that one or more walls of the socket may be partly or completely missing either due to the normal anatomy of the site, pre-existing inflammatory processes or damage as a complication of the tooth extraction procedure. For these reasons, bone regeneration around early placed implants may be necessary and performed by using a variety of bone augmentation or guided bone regeneration techniques [2,7]. A common and successfully documented route is the use of particulate bone substitutes such as allografts, xenografts and synthetic materials (alloplasts), with or without a barrier membrane [8,9].

These bone substitutes vary in terms of origin, composition and biological mechanism of function regarding graft resorption and new bone formation, each having their own advantages and disadvantages [10].

The ideal bone grafting material should have specific attributes [11]. It should be osteoconductive, osteoinductive and biocompatible. It is important to be fully replaced by host bone having an appropriate resorption time in relation to new bone formation and it should be able to maintain in the long-term the volume of the augmented site. Moreover, it should have satisfactory mechanical and handling properties and no risk of disease transmission.

Synthetics represent a group of alloplastic, biocompatible bone substitutes. These biomaterials are free of any risk of transmitting infections or diseases by themselves, which might be an issue when utilizing xenografts or allografts. Moreover, their availability is unlimited in comparison to autogenous bone. One of the most promising groups of synthetic bone substitutes are calcium phosphate ceramics. Calcium phosphate ceramics combine good stability with porosity and interconnectivity, and they are non-toxic during the dissolution and degradation process. Moreover, they allow the adhesion and growth of multipotent mesenchymal stem cells and osteoblasts and there is strong experimental evidence that calcium phosphates have also osteoinductive properties, apart from being osteoconductive [12-14]. Among calcium phosphate ceramics, β-TCP is commonly used in clinical practice [14-18]. It should be distinguished from hydroxyapatite, which is hardly degradable at all [14]. Adding CS to β-TCP produces an in situ self-hardening grafting material that binds directly to the host bone [19]. The improved stability throughout the scaffold of the graft seems to further improve the quality of the bone to be regenerated due to reduced micro–motion of the material. It is known

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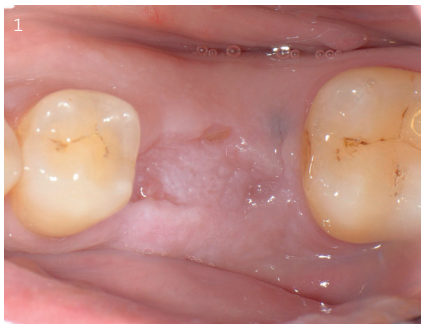
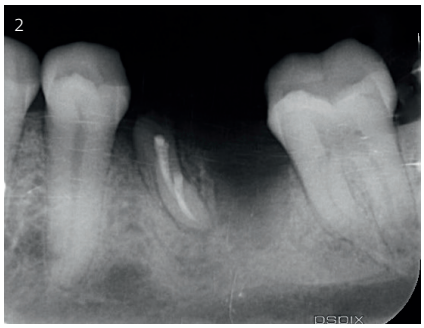
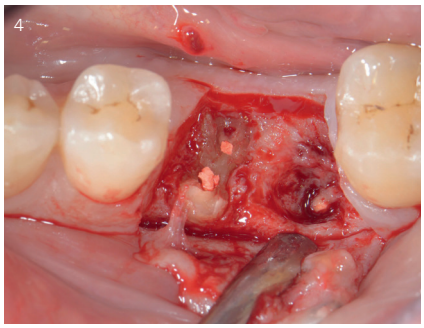


1 Clinical view four weeks after extraction.



2 I Initial x-ray.



3 I Site-specific flap revealing the post-extraction socket and the residual part of the mesial root.

that micro-movements between bone and any implanted grafting material may lead to mesenchymal differentiation to fibroblasts instead of osteoblasts and prevent bone formation, resulting in the development of fibrous tissue [21,22]. It is also important that the CS can act as a barrier, halting the ingrowth of soft tissue during the early phases of bone regeneration [20]. The CS element will quickly resorb over a three to six week period depending on patient physiology, which will release calcium at the site and increase the porosity in the β-TCP scaffold for improved vascular and cell ingrowth and improved angiogenesis and osteogenesis [14,23,24]. The β-TCP element, the scaffold for the bone regeneration, will then resorb over a period of nine to sixteen months again dependent on host physiology leading to true regenerated host bone [14,17].

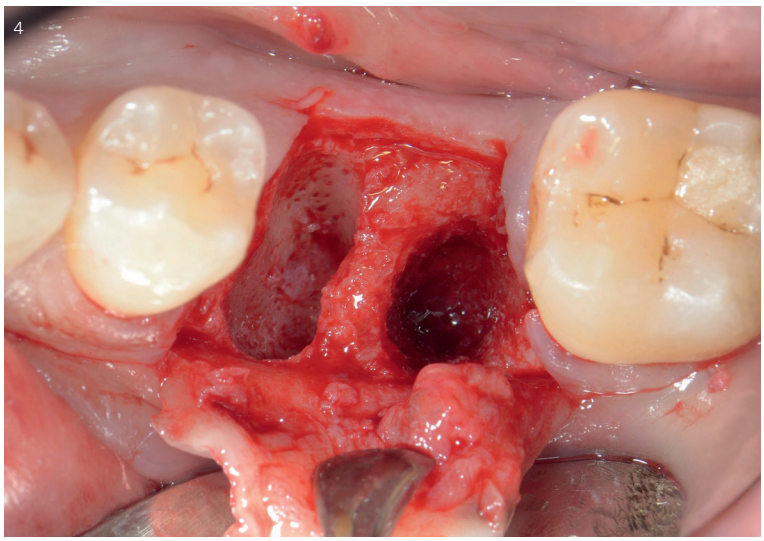
The purpose of this report is therefore to present a case of early placement of an implant into a defective molar socket with simultaneous bone grafting with an in situ hardening β-TCP/CS material, following a standardized protocol, as described by the authors in a previous publication [4].

Case report

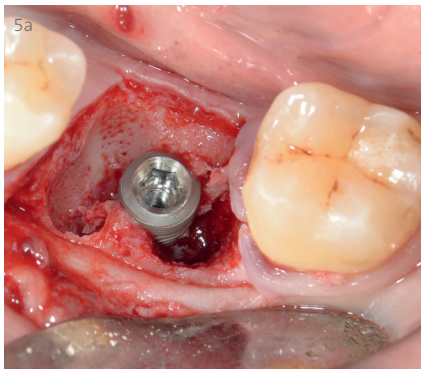
A 60-year-old male patient, non-smoker, without medical contraindication for implant therapy was referred by his general dentist for rehabilitation of the edentulous site 36. The referring dentist had extracted in a non-surgical way the failing lower left first molar four weeks ago. During extraction, a part of the mesial root was broken and left behind. The dentist did not want to perform a surgical extraction and informed the patient that the root would be removed at a second stage, probably at implant placement if possible. At presentation, the post-extraction site was covered by newly-formed soft tissue, regenerated by secondary intention healing (Fig. 1). There were no clinical signs of infection and the residual root was submerged under the soft tissue. Radiologically, a periapical x-ray showed the residual part of the mesial root with no evidence of pathology in the surrounding bone, while the septal bone seemed intact (Fig. 2). As there were no signs of infection, it was decided to treat the case as an early implant placement with simultaneous bone grafting, according to a standardized protocol published by the authors [4]. Following this simplified protocol, the treatment plan consisted of:

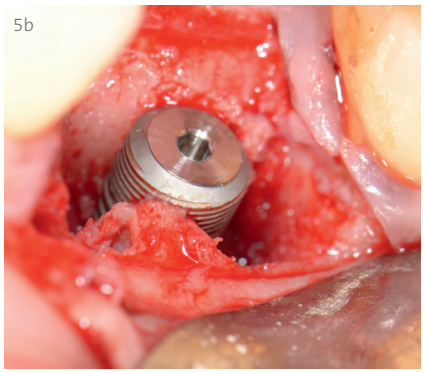
- Implant placement at the four weeks healed socket with extraction of the part of the residual root;
- Simultaneous bone grafting with an in situ hardening synthetic resorbable bone substitute composed of β-TCP and CS;
- Loading of the implant at twelve weeks post-op.

Under local anesthesia, a site-specific full thickness flap was raised using vertical releasing incisions, without including the papillae of the adjacent teeth (Fig. 3). After flap elevation, the residual root was mobilized and removed with a thin elevator. Subsequently, the site was thoroughly curetted and debrided of any granulation tissue with bone curettes and degranulation burrs (Degranulation Kit; EK-Solution, Beit Kama, Israel) (Fig. 4).

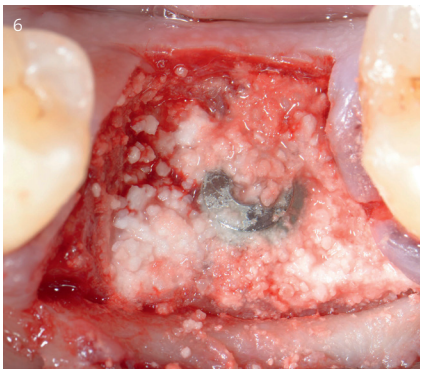


4 I Clinical view after extraction of the root and thorough debridement of the site.

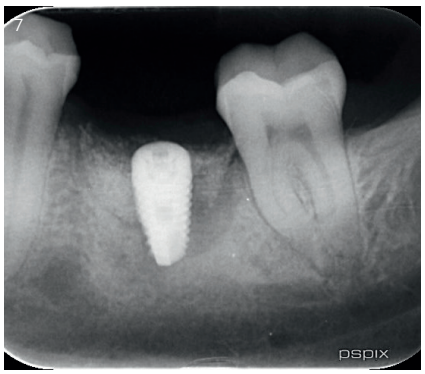




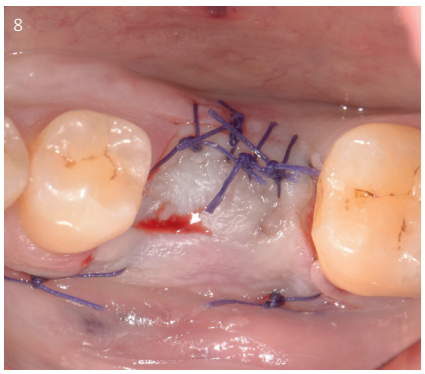
5a and b I Implant placed at the correct 3D positioning. Note the bone defect between the implant surface and the surrounding bone walls.



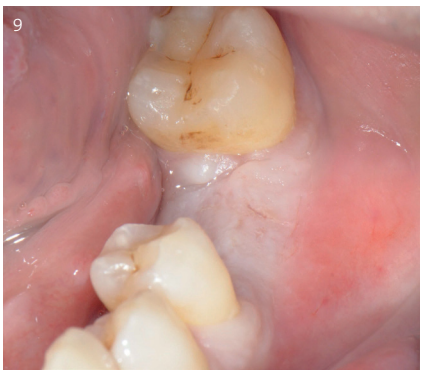
6 I Bone grafting with β-TCP/CS (ethoss).



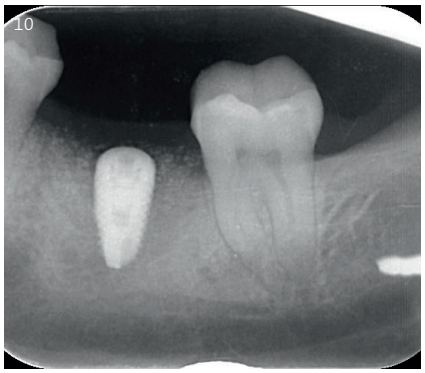
7 I Periapical radiographs immediately after implant placement and bone grafting.



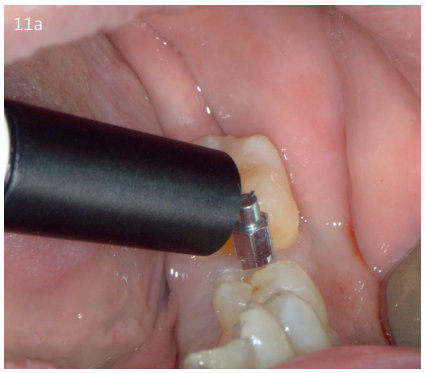
8 I Tension-free closure.



9 I Clinical view after ten weeks.

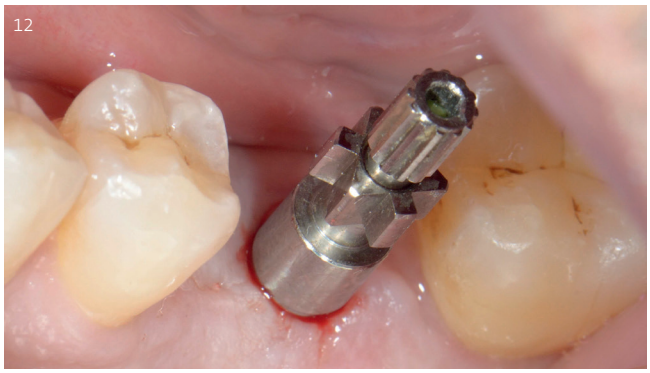


10 I X-ray ten weeks after implant placement and grafting showing the consolidation of the grafting material around the implant.

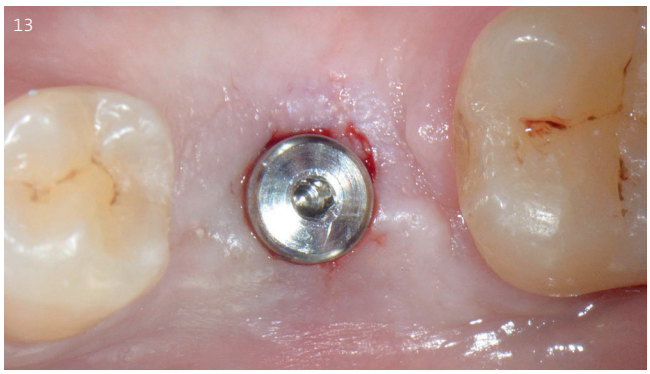


11a and b I ISQ measurement showing high secondary implant stability.

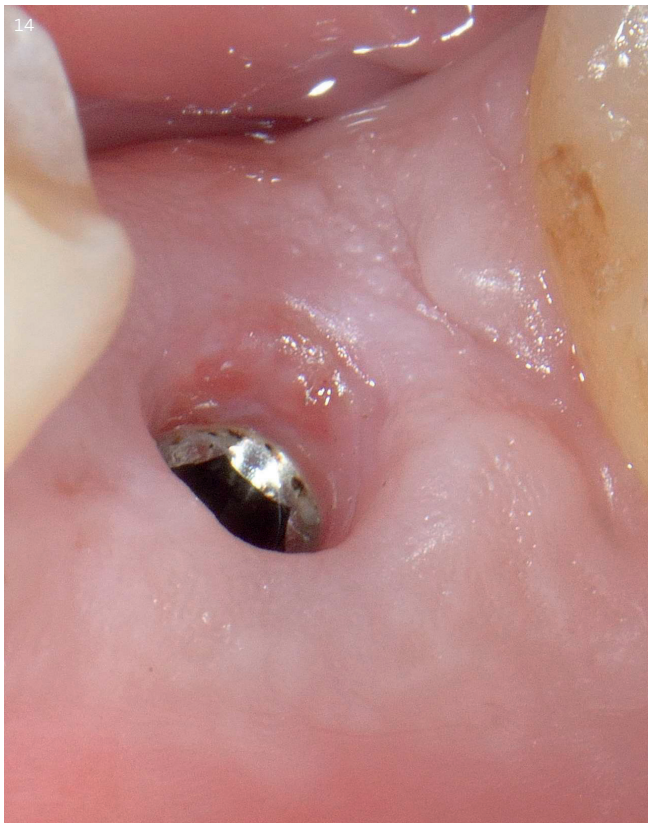
A 5 mm x 10 mm implant (Paltop Advanced Dental Solutions Ltd, Caesarea, Israel) was placed at the optimal position (Figs. 5a and b). After placing the cover screw, the site was augmented utilizing a self-hardening resorbable synthetic bone grafting material: ethoss (Ethoss Regeneration Ltd., Silsden, UK) is a novel biphasic bone substitute consisting of β-TCP (65 per cent) and CS (35 per cent). The grafting material comes in a delivery syringe where the piston is drawn back and sterile saline added to the powder. It is allowed to seep through the particles and then the excess is discarded by compression into a sterile gauze. The hydrated material is now taken to the surgical site and extruded into the defect, then compressed with another gauze using an instrument to pack the material into any cavities. The gauze is then held over the graft for three to four minutes until the CS element has set hard, making sure to restrict the adjacent blood to the material site and remembering not to overfill the site for tension free closure. No barrier membranes were used (Figs. 6 and 7). The mucoperiosteal flap was repositioned and sutured without tension with 4-0 sutures (Vicryl, Ethicon; Johnson & Johnson,



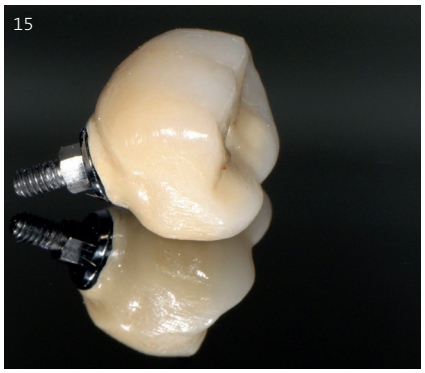
12 I Open-tray impression coping.

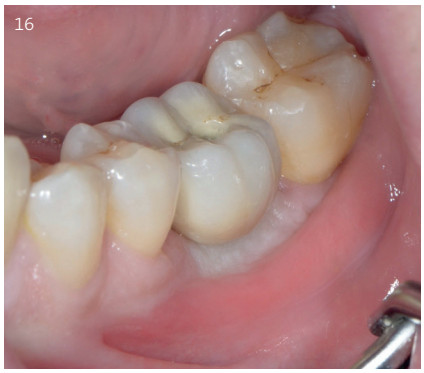


13 I Occlusal view after placing of the healing abutment.

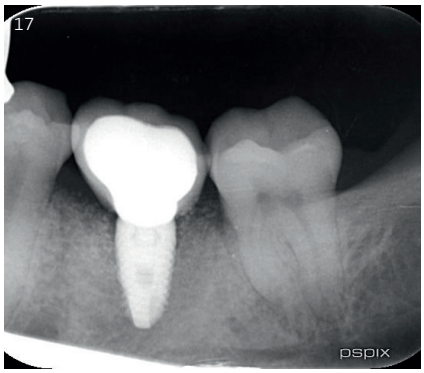


14 I Maturation of the soft tissues two weeks after placement of the healing abutment.





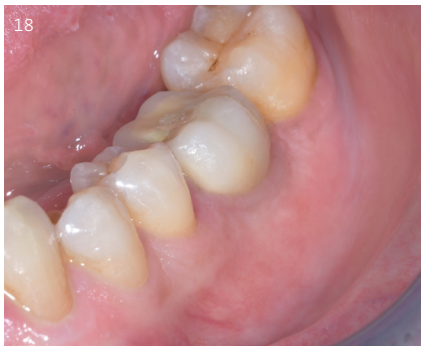
15 and 16 I Screw-retained metal-ceramic crown fitted and torqued at 35 Ncm.

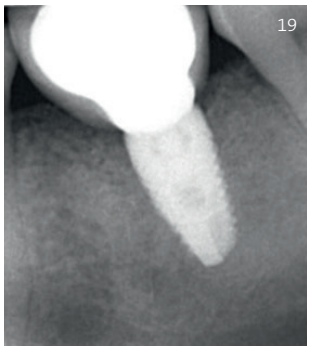


17 I X-ray immediately after fitting the implant crown.

Somerville, NJ, USA) (Fig. 8). The patient did not wear any prosthesis during the healing period. Antibiotic therapy consisting of 500mg amoxicillin every eight hours for five days and mouth rinsing with 0.2 % chlorhexidine every eight hours for ten days were prescribed. The sutures were removed after a seven-day healing period.

After ten weeks, the healing was uneventful. The architecture and the dimensions of the ridge were adequately preserved and the site was covered with thick keratinized epithelium (Fig. 9). A periapical x-ray showed excellent osseointegration of the implant and consolidation of the grafting material (Fig. 10). A tissue punch was used to expose the implant and the secondary stability of the implant was measured by resonance frequency analysis (PenguinRFA; Integration Diagnostics Sweden AB, Göteborg, Sweden). An ISQ-value (Implant Stability Quotient) of 76 was recorded demonstrating high stability (Figs. 11a and b). Subsequently, an open-tray impression was taken and a healing abutment was placed (Figs. 12 and 13). A screw-retained crown was fitted after two weeks with excellent aesthetic and functional results (Figs. 14 to 17).





18 and 19 I Clinical view and x-ray one year after loading of the implant.

Follow-up clinical examination one year after loading revealed stable peri-implant keratinized soft tissues with excellent preservation of the volume and architecture of the ridge (Fig. 18). A periapical x-ray showed further functional remodeling of the bone around the loaded implant with no radiological findings of residual biomaterial (Fig. 19).

Discussion

In the presented case, the post-extraction site was allowed to heal for a four-week period and an early implant placement procedure was followed. This four-week period enabled the spontaneous production of adequate newly formed keratinized soft tissue over the post-extraction socket, and so, tension free primary closure could be achieved at implant placement and grafting without the need of advancing the flap coronally. In this way, the mucogingival junction was not displaced and the buccal keratinized mucosa was preserved, resulting in a pleasant and stable aesthetic final result without distortion of the vestibule [25].

Placement of the implant and the grafting material at four weeks after the extraction takes advantage of the enhanced and activated host bone-healing environment of the post-extraction site [6,16]. Also, it has been found that the implant itself, due to its semi-conductive nature, increases local bone metabolism and plays a part in the host hard tissue regeneration. Thus, early placement at four weeks with earlier loading at eight to twelve weeks, subject to suitable ISQ measurements, both have a positive effect, increasing the bone metabolic activity and regeneration [26].

The full resorption of bone substitutes like β-TCP and CS will lead to the regeneration of vital bone at the site without residual biomaterial. This is of great importance clinically as the long-term presence of residual non-resorbable or slowly resorbable graft particles might interfere with normal bone healing and remodeling, may reduce the bone-to-implant contacts and have a negative effect on the overall quality and architecture of the bone that surrounds the implant [27]. However, there are concerns that the full resorption of the biomaterial may contribute to site collapse. In this case, although a resorbable biphasic β-TCP/CS graft was used for bone regeneration, the architecture and dimensions of the ridge were preserved one year after loading of the osseointegrated implant. The stability of the buccal mucosa, shown clinically, indicates the stability of the underlying bone. A possible explanation is that the early loading of the implants twelve weeks after placement, as proposed in the authors' protocol [4], enhances the metabolic activity and triggers the remodeling of the regenerated bone around the implant. Assuming that the newly-formed hard tissue around the implant is vital bone with no residual graft particles, it can be concluded that it adapted successfully to the transmitted occlusal forces according to *Wolff*'s law, became stronger to resist to that sort of loading and thus maintained the bone mass and volume [28].

Finally, the non-need for a separate barrier membrane, as shown in this case, significantly reduced the surgical time and cost and may be attributed to enhanced bone regeneration as the periosteum was not isolated from the grafted site. The periosteum has been shown to play a pivotal role in bone graft incorporation, healing and remodeling, as it contains multipotent mesenchymal stem cells that are capable of differentiating into bone and cartilage, and provides a source of blood vessels and growth factors [29-31].

Conclusion

In the presented case, an in situ hardening resorbable synthetic bone substitute was used according to a standardized protocol for bone augmentation in parallel to early implant placement, resulting in pronounced hard tissue regeneration and enhanced implant stability in order to load the implant twelve weeks post-op. The in situ hardening and handling properties of the grafting material may enable clinicians to utilize simplified techniques in achieving successful functional and aesthetic results for implant rehabilitations. Moreover, the fully resorbable nature of this bone substitute ensures that no residual particles of the material will be present in the newly-formed hard tissue in the long term, promoting the regeneration of vital bone which can be successfully loaded and remodeled.

The references are available at www.teamwork-media.de/literatur

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