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Socket seal surgery: Clinical uses in implant dentistry and guided bone regeneration procedures for single tooth replacement in the esthetic zone

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Restoring failing anterior teeth with a dental implant is considered a complex treatment even with thorough biologic knowledge of the situation. The goal is to produce a result in which the labial soft tissues and the papillae remain stable over time. Treatment of the fresh extraction socket in the alveolar ridge presents a challenge in everyday clinical practice. Regardless of the subsequent treatment, maintenance of the ridge contour will frequently facilitate all further therapeutic steps. Socket seal surgery and socket preservation in combination with immediate, early, or delayed implant placement can be valuable procedures for single tooth replacement. However, their potential as ridge preservation techniques in these different situations still needs to be demonstrated. The use of these procedures is illustrated in three consecutive cases. *(Quintessence Int 2016;47:123–139; doi: 10.3290/j.qi.a34455)*

Key words: delayed implant placement, early implant placement, immediate implant placement, socket preservation, socket seal surgery

Tooth removal is always followed by the loss of vital soft and hard tissues. When occurring in the anterior region of the maxilla, the resulting ridge deformation may cause severe functional and esthetic problems.

The consequent resorptive process leads to the formation of tissue defects which are associated with the vertical and horizontal dimensions of the interproximal tissue and the vertical and horizontal dimensions of tissue on the midbuccal aspect of the future restoration.[1] This is particularly relevant for treatments involving the placement and reconstruction of dental implants. It has been demonstrated in numerous animal and clinical studies that following tooth extraction undisturbed wound healing will lead to loss of ridge volume and change in ridge shape.[2] The goal today is to manage implant treatments with better understanding of the factors that provide a durable esthetic result, especially with respect to the soft tissue esthetics.[3]

Diverse soft and hard tissue regenerative procedures have been developed for correcting ridge defects with the aim of establishing functional and esthetically pleasing pontic or implant restoration sites.

The aforementioned dimensional changes of the alveolar ridge may complicate the subsequent restora-

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tive procedures when dental implants are chosen. Over the past 20 years, increasing interest has arisen regarding a concept called "alveolar ridge preservation", which was defined as "any procedure undertaken at the time of or following an extraction that is designed to minimize external resorption of the ridge and maximize bone formation within the socket".[4,5]

A recent systematic review concluded that the reasons for ridge preservation included:[6]

- maintenance of the existing soft and hard tissue envelope
- maintenance of a stable ridge volume for optimizing functional and esthetic outcomes
- simplification of treatment procedures subsequent to the ridge preservation
- generation of a good soft tissue volume for the time of implant placement thus simplifying implantation procedures at earlier time points
- generation of a good hard tissue volume for the time of implant placement thus simplifying implantation procedures at later time points.

Another systematic review evaluated the efficacy of these therapies in non-molar alveolar regions suggesting that these techniques may not prevent the physiologic resorptive bone processes after tooth extraction, although they may aid in reducing the resulting bone dimensional changes.[7]

Regarding timing for implant placement, some consensus statements have been addressed in the literature:[2]

- Immediate implant placement leads to high implant survival rates but it is associated with a high risk for mucosal recession.
- Augmentation of soft and hard tissues is frequently necessary.
- The procedure of immediate implant placement into extraction sockets should be used very restrictively in the esthetic area.
- Immediate implant placement is primarily recommended in premolar sites with low esthetic importance and favorable anatomy.

The effect of membrane placement in conjunction with or without bone substitutes for preserving the alveolar bony walls around implants immediately placed into extraction sockets of the anterior region was studied in patients that randomly received immediate implants with deproteinized bovine bone material (DBBM) + collagen membrane, DBBM alone, or were left ungrafted. This clinical study demonstrated that the bone defect around the immediately placed implants will heal predictably irrespective of the usage of membranes or bone grafts. However, the membrane or bone graft treatment may reduce the horizontal resorption of the buccal bony plate by 25% of the original dimension.[8] Other clinical studies concluded that peri-implant soft tissue recession is a major esthetic complication in immediate implant protocols, especially in the anterior maxilla.[9,10] Several published prospective case series using the early implant placement protocol have reported excellent intermediate to long-term esthetic results.[11,12] These results lend additional support to the recommendation of type II (early) instead of type I (immediate) implant placement following tooth extraction in esthetic sites.

The placement of free soft tissue graft to cover the augmented alveolar socket was introduced to minimize the soft tissue shrinkage, optimize esthetic results of implant restoration, and obtain a primary closure that may preserve the graft from bacterial infections and secondary graft failure.[13,14] The first attempt to cover the socket graft with an autogenous soft tissue implant was described by Landsberg and Bichacho.[15] Nevins and Mellonig[16] suggested the use of soft tissue grafts to improve ridge topography after tooth extraction[16] and in combination with immediate implant placement.[17]

Regarding soft tissue remodeling, a previously published clinical study showed that different alveolar ridge preservation techniques were not able to entirely compensate for alveolar ridge reduction as well when evaluating optically scanned cast models.[18] In general there are very limited data in the dental literature available on soft tissue volume changes after tooth extraction using different techniques for alveolar ridge preservation.

The socket seal surgery procedure could be understood as a preventive measure to minimize these dimensional changes to be used at the time of tooth extraction combined with spontaneous healing and early implant placement; with immediate implant placement; or with ridge preservation techniques and delayed implant placement.

APPLICATION/CLINICAL TIPS

When deciding to perform the socket seal surgery procedure, the presurgical conditions and the surrounding marginal soft and hard tissues must be analyzed carefully. The extraction of the tooth with minimal trauma to the surrounding tissues has a positive effect on post extraction defect formation and is a key factor for the success of the protocol presented.

The survival and integration of soft tissue grafts depend on a number of factors, including the quality of the blood supply to the affected tissues and the prevention of bacterial infection. Primary wound closure over natural or artificial graft material ensures that healing will occur in an environment that is impossible or very difficult for microorganisms to enter.[1]

It must be considered that the conditions for survival of the free gingival grafts in the recipient bed are less favorable than those for connective tissue grafts. The parts of the graft with epithelium in the socket seal procedures are not covered by a flap with blood supply and remain exposed to the oral cavity. Hence, the clinician must consider the factors for graft survival when the graft is harvested as well as the factors related to recipient site preparation. Moreover, this protocol is not recommended in heavy smokers or patients with poor oral hygiene and it must be utilized after careful case selection with meticulous soft tissue management (Fig 1). According to the authors' experience, several guidelines should be considered:

1. The soft tissue opening dimensions over the extraction socket must be precisely measured before the graft is harvested.
2. The presence of interproximal papillae at the recipient site is crucial for optimal revascularization of the graft.
3. Because the palatal mucosa is thickest in the premolar region, it is advisable to harvest thick grafts from this region; however, in order to avoid healing problems, periosteum should be left on the bone.
4. The graft must be thick enough (2 to 3 mm), for an optimal wound surface area accessible to diffusion and revascularization in the recipient bed.
5. The harvesting of slightly "overextended" grafts appears to have additional advantages in terms of optimal shape adaptation. Standard circular punches are not recommended for harvesting this kind of graft. Instead, the tissue should be harvested with a scalpel.
6. To ensure good integration of the soft tissue graft, a microblade or a carbide bur is used to de-epithelialize the marginal gingiva on the side facing the extraction socket while simultaneously creating a bleeding wound surface.
7. According to the authors' preference, 5/0 and 6/0 nylon monofilament polypropylene or polyamide are the most suitable suture materials.
8. A periodontal dressing or a stent can be placed at the donor site to achieve hemostasis and minimize patient discomfort.

Socket seal surgery and immediate implant placement

The primary goals of immediate implant placement are to shorten the time of treatment and reduce cost and effort, while enhancing patient comfort. The conditions for when this protocol is indicated should include: the integrity of the alveolar bone walls, facial bone thickness, the soft tissue biotype, scalloping, tooth shape, and emergence profile.[2,3] Moreover, some authors reported that immediate implant placement does not preserve the bony structures of the alveolar process nor avoid the soft and hard tissue remodeling.[19] Some clinical trials have shown that soft tissue recession can also be expected after immediate implantation and loading of implants.[20,21] The magnitude of recession varied greatly in different studies, suggesting that it is very difficult to predict the behavior of the soft tissue after immediate implant placement. When implant surgery is to be performed in a single-stage approach, a flapless

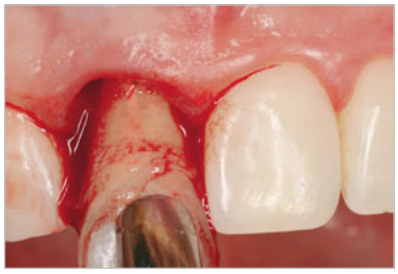


Fig 1a Careful tooth extraction is important for a predictable outcome.

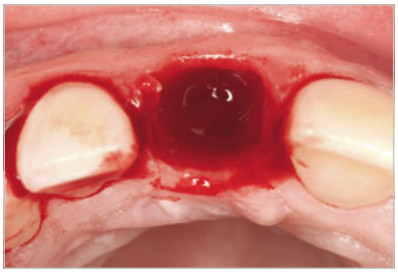


Fig 1b After tooth extraction, the integrity of surrounding soft tissues must be confirmed.

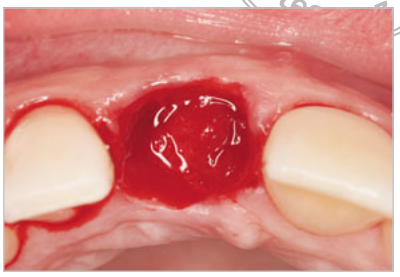


Fig 1c The application of a collagen plug into the socket provides stabilization of the blood clot and mechanical support for the free gingival graft.

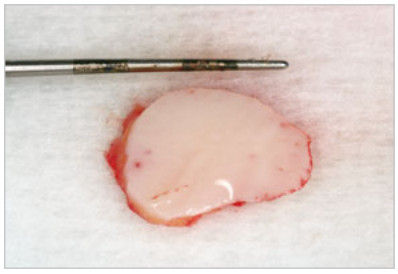


Fig 1d Appropriate diameter and thickness are crucial for the survival of the graft.

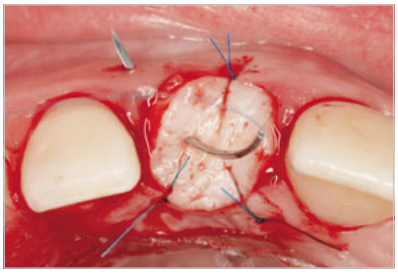


Fig 1e It is advisable to pass the needle through the graft first and then through the recipient site edge.

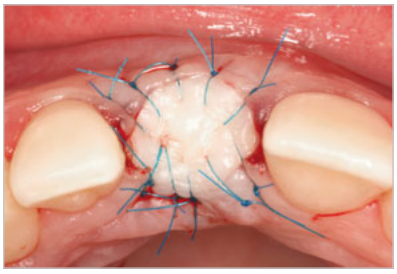


Fig 1f As many as necessary interrupted sutures are placed until no space is noticed between graft and recipient site margins.

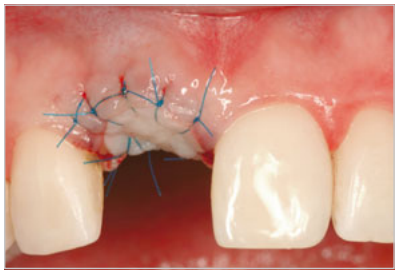
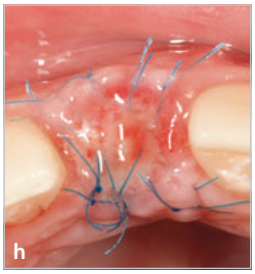


Fig 1g Knots should be displaced to the buccal and palatal margins respectively.

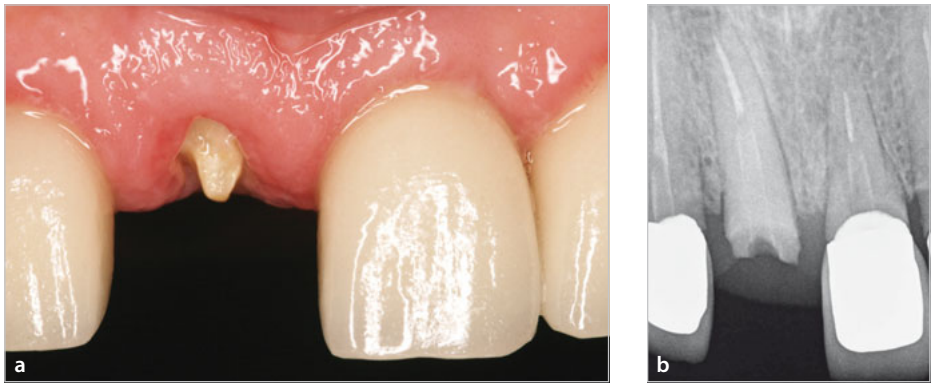


Figs 1h to 1j Healing was evaluated at *(h)* 1 week, *(i)* 2 weeks, and *(j)* 6 weeks.

protocol is preferred because it prevents additional bone resorption from the exterior.[22,23] In this context, socket seal surgery at the time of immediate implant placement when using a flapless protocol could help to stabilize the marginal soft tissues, allowing primary wound closure, in cases when immediate provisionalization is not possible or planned.

CASE 1

A 58-year-old man presented a vertical fracture on the maxillary right central incisor. The tooth was previously treated with endodontic therapy, a post, and an all-ceramic crown. The fracture was situated 3 mm below the gingival margin in the facial aspect and the remaining root fragment was considered unsalvageable. The marginal soft tissues were considered optimal for achieving primary wound closure after an immediate implant placement and simultaneous grafting procedure (Fig 2). During the extraction, care was taken not to damage the surrounding soft tissues. The socket was assessed to confirm the integrity of the bone walls, and the inner marginal edges of the soft tissues were de-epithelialized with a diamond bur. A 4 × 13 mm tapered



Figs 2a and 2b Preoperative *(a)* clinical view and *(b)* radiograph.

implant (T3 Tapered Implant, Biomet 3i) was inserted according to the correct three-dimensional positioning. The buccal aspect of the socket and the peri-implant spaces were filled with DBBM (Endobon, Biomet 3i) after the implant insertion. Although good primary stability was achieved, immediate provisionalization was considered a risk factor. A collagen membrane (Evolution, Osteobiol) was trimmed and adapted to the socket for covering the implant and the xenograft. A free gingival graft was harvested from the palate according to the socket dimensions. A horizontal mattress suture was placed on the buccal aspect to stabilize the graft in the recipient site. Closure was completed with interrupted sutures on the buccal and palatal sides. The removable provisional device was contoured to ensure there was no contact with the surgical site. The sutures were removed 10 days after the surgery. Healing occurred without complication during the following 3 months. Good integration of the graft was evident and the buccolingual ridge dimension was maintained. After 5 months, the stage-two surgery was performed with a modified roll flap technique. Simultaneously, an impression was taken for a screw-retained provisional crown. After the soft tissue conditioning phase that normally takes 3 to 4 months, another impression was taken and the definitive all-ceramic crown was installed (Fig 3).The soft tissue stability was confirmed after a 2-year follow-up visit (Fig 4).

Socket seal surgery and early implant placement

It is well known that the early placement protocol is indicated when some damage to the buccal and/or interproximal bone plate is expected.[24,25] When performing guided bone regeneration combined with early implant placement (4 to 8 weeks after extraction), the conditions of closed healing are mandatory.[26,27] The use of socket seal surgery at the time of extraction will provide a scenario where the socket will be covered with mature, thick, and well-keratinized tissue at the marginal level and over the extraction site, eliminating the soft tissue invagination into the inner part of the socket after 6 to 8 weeks of soft tissue healing. This will give several advantages, such as the execution of a clean midcrestal incision, the possibility of horizontal improvement of the volume, and the facility to achieve primary wound closure and closed healing of the implant and grafting materials, minimizing the risk of displacement of the mucogingival junction in a coronal direction.

CASE 2

A 35-year-old woman presented a vertical fracture on the maxillary left central incisor. The tooth had been previously treated with endodontic therapy and a porcelain-fused-to-metal crown. The mobility of the crown was evident at clinical assessment with pain and slight inflammation of the marginal tissues (Fig 5). The tooth

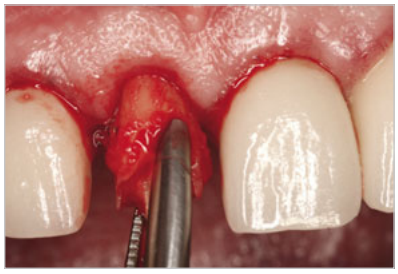


Fig 3a The root fragment was removed with axial forces.

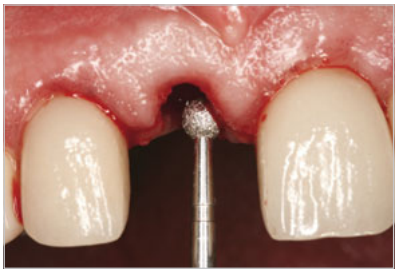


Fig 3b A round diamond bur was utilized to de-epithelialize the marginal gingiva on the inner edges of the socket.

Fig 3c The tapered implant was inserted. Correct three-dimensional positioning was previously confirmed with a surgical guide.

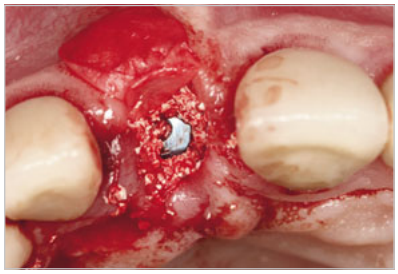


Fig 3d The buccal aspect and all the peri-implant spaces were filled with DBBM and a collagen membrane was trimmed and adapted to the socket. At the facial aspect the membrane was introduced coronally into the split thickness tunnel.

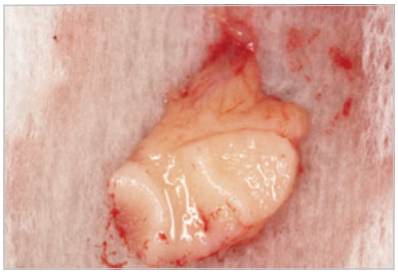


Fig 3e The free mucosal graft was harvested from the palate according to the socket dimensions. The graft was harvested with maximum thickness and a connective tissue pedicle to be situated into a buccal tunnel previously prepared.

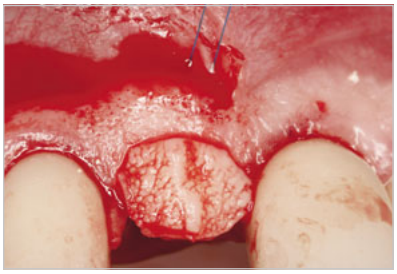


Fig 3f A horizontal mattress suture was placed on the buccal aspect passing through the connective tissue pedicle and slightly coronal to the mucogingival junction.

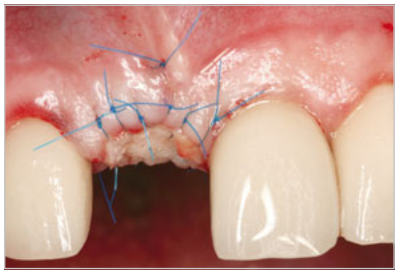


Fig 3g Closure was completed with interrupted sutures.

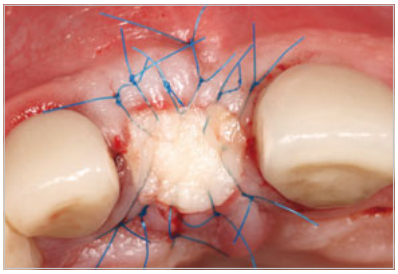


Fig 3h Exact approximation of the wound margins was checked to minimize the diffusion distance to the graft during the first days.

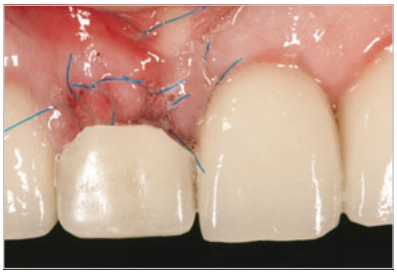


Fig 3i The removable provisional device was contoured to create space between the tooth and the surgical site. This would avoid contact during the first days in which some inflammation may occur.

was considered hopeless and the decision was made to perform early implant placement. After an atraumatic extraction, the socket was evaluated, and although the labial plate was intact in the coronal third, there was a considerable apical lesion and a fenestration of the buccal bone wall was noticed. A socket seal technique was considered in order to preserve the labial contours. The socket was degranulated and debrided. A collagen plug (Collaplug, Zimmer) was introduced and packed into the socket in order to stabilize the blood clot. In the authors' experience, this collagen dressing also provides support and stability to the mucosal graft. A free gingival graft was harvested from the palate and precisely sutured to the socket margins. A bonded Maryland bridge was adjusted and fitted, ensuring that there was no pressure or contact on the site. Complete healing was observed

Fig 3j Healing was assessed at 2 weeks.

Figs 3k and 3l Healing at 4 weeks: *(a)* occlusal view, *(b)* anterior view.

Fig 3m After 5 months, the stage-two surgery was performed. A screw-retained provisional restoration was fitted and left in place for 3 months.

Fig 3n The transition zone was created according to the desired emergence profile.

Fig 3o Finally, a screw-retained all-ceramic crown was adjusted.

Figs 4a and 4b At the 2-year follow-up visit, the peri-implant soft tissues remained stable: *(a)* anterior view, *(b)* occlusal view.

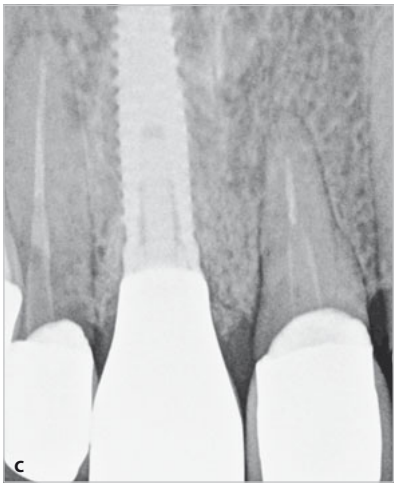
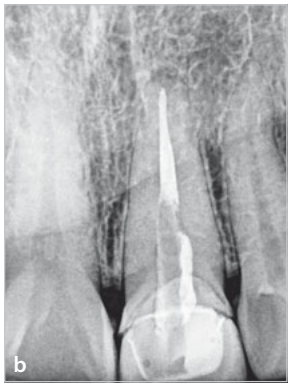


Fig 4c The bone stability around the implant was verified radiographically.



Figs 5a and 5b Preoperative situation: *(a)* clinical view and *(b)* radiograph.

Fig 6a The tooth was extracted and the socket was debrided. A collagen plug was inserted into the socket.

Fig 6b The collagen plug was packed in order to stabilize the blood clot and improve mechanical stabilization of the graft.

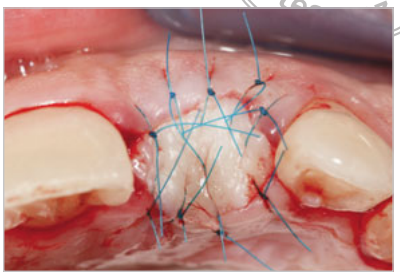


Fig 6c The socket seal procedure was performed at this stage.

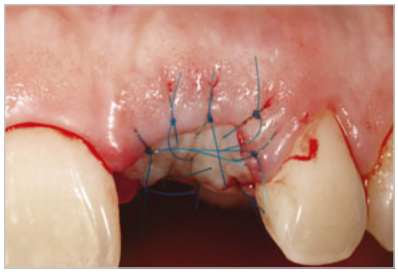


Fig 6d Stable primary closure is considered crucial to minimize the risk of necrosis.

Fig 6e A space was left between the base of the bonded provisional restoration and the graft to allow dimensional changes after the initial inflammatory phase.

Fig 6f Complete healing was observed 8 weeks after extraction, allowing an optimal scenario for implant placement and reconstruction of the alveolar ridge.

Fig 6g Soft tissue conditions were ideal for augmentation with predictable primary wound closure.

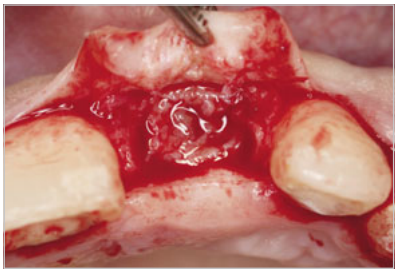


Fig 6h A midcrestal incision allowed the elevation of a combined full-split thickness buccal flap.

Fig 6i The implant was inserted slightly subcrestal in relation to the buccal crest.

after 8 weeks, at the moment of implant placement. A midcrestal incision was made and a combined full and split thickness flap was elevated to ensure defect visualization. All the connective tissue was carefully removed from the inside of the socket and a 4 × 13 mm tapered implant (T3 Tapered Implant, Biomet 3i) was inserted in the correct three-dimensional position. DBBM (Endodon, Biomet 3i) was placed on the exposed implant surface inside the socket and over the buccal bone wall in order to improve the volume. A standard collagen membrane (OsseoGuard Flex, Biomet 3i) was trimmed and fitted in two layers covering the buccal aspect and the middle part of the ridge. Single interrupted sutures were then used in the midcrestal incision. Healing occurred with no complications and sutures were removed after 12 days. Five months after the implant placement the stage-two surgery was programmed. A modified roll technique was used and the provisional restoration was cemented 7 days after this procedure. The implant-supported provisional crown was used for 3 months to create an ideal emergence profile and transition zone. Finally, the impression was taken and the definitive all-ceramic crown was cemented (Fig 6). The 1-year follow-up revealed good soft tissue stability (Fig 7).

Fig 6j DBBM was then placed in the inner part of the buccal bone plate, surrounding the implant, and over the facial bone.

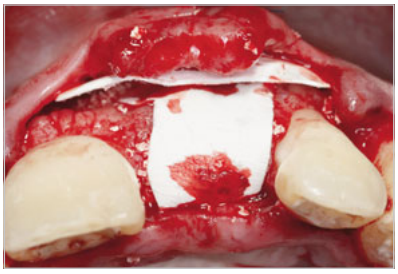


Fig 6k A collagen membrane was placed in a crossed fashion to cover the buccal and midcrestal part of the ridge.

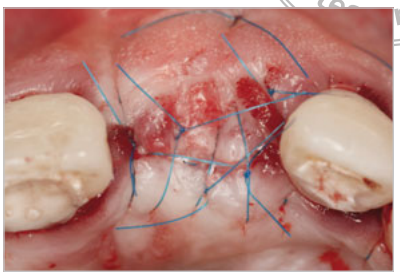


Fig 6l Interrupted sutures were used in the midcrestal incision (note the improvement of the horizontal volume and the absence of tension).

Fig 6m The implant-supported provisional restoration was inserted after 4 months.

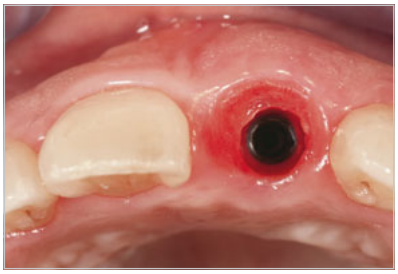


Fig 6n Modifications of the margins were done to create a balanced emergence profile. The transition zone was considered optimal for the final crown placement.

Fig 6o An all-ceramic crown was cemented on a screw-retained zirconia abutment.

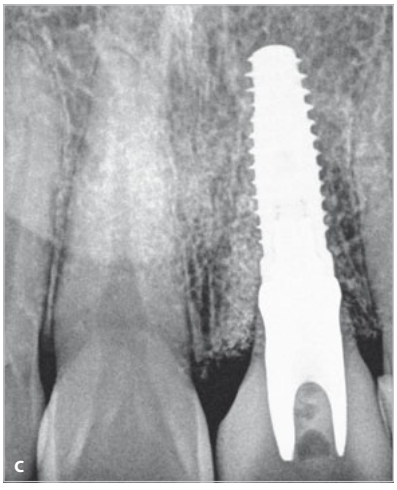


Fig 7a At the 1-year follow-up visit, the peri-implant soft tissues remained stable.
Fig 7b The occlusal view shows the effect of the augmentation procedure.
Fig 7c The radiograph confirmed the peri-implant bone stability.

Socket seal surgery combined with ridge preservation techniques and delayed implant placement

Various alveolar ridge preservation techniques have been described in the literature, including suturing mucosal grafts to the margins of the extraction socket, augmenting the buccal soft tissue with subepithelial connective tissue grafts, and filling extraction socket with autogenous bone or bone substitute materials.[6,28-30]

Landsberg and Bichacho[15,17,31,32] described a method of socket seal surgery in which the extraction socket is filled with bone substitute material and covered with a thick free gingival graft to prevent ridge resorption and enhance bone regeneration. This modified ridge preservation technique combines bone and soft tissue grafting and is performed prior to implant placement. The protocol has been suggested to achieve optimal outcome in the replacement of extracted maxillary anterior teeth.

Histologic studies have shown that, although the incorporation of DBBM in the extraction socket results in altered and delayed osseous healing, it is also able to compensate the volumetric changes in the alveolar ridge, at least to a certain extent.[7,22,30]

At this point, the envelopment of part of the filling material with connective tissue or a free gingival graft at the coronal aspect is a critical concern since it will contribute to achieving close healing, clot stabilization, and minimizing the encapsulation of xenograft particles by "ingrowing" connective tissue from the margins of the socket on the first weeks of healing. If the soft tissue graft undergoes dehiscence in the wound margins or partial necrosis, some DBBM particles can be lost during the first weeks of healing. In the authors' experience, this event does not jeopardize the final volumetric outcomes.

CASE 3

A 46-year-old woman presented a large apical lesion around the maxillary left lateral incisor. The clinical assessment showed a fistula and slight inflammation of the apical area. The presence of acute infection, the shape and size of the defect, and the lack of predictability for a correct three-dimensional positioning of the implant determined that a delayed placement protocol should be followed (Fig 8). The tooth was atraumatically removed, and a thorough degranulation and disinfection of the socket was performed with local antibiotics. The socket was also irrigated with 0.2% clorhexidine and sterile saline solution. Although the labial bone plate was intact, there was a considerable apical lesion. A free gingival graft was harvested from the palate and stabilized with two interrupted sutures on the buccal margins of the socket. A collagenized porcine xenograft (MP3, Osteobiol) was packed into the socket and apical bone defect. The graft was then covered with a trimmed collagen plug (Collaplug, Zimmer) at the marginal level of the socket. The free gingival graft was repositioned and stabilized with interrupted sutures for sealing the grafted socket. A bonded provisional restoration was adjusted and fitted, ensuring that there was no contact with the site. Sutures were removed at 12 days. Healing was uneventful; and at 6 months a good preservation of the ridge and gingival architecture was observed. Nevertheless, a remodeling from the outer part of the buccal bone plate was evident. At this moment, the implant placement was planned. A midcrestal incision was made, and a small full-thickness flap was elevated. Some xenograft particles were still visible. However, a good integration of the biomaterial was noticed. The osteotomy was made and a tapered implant (3.4 × 11.5 mm T3 tapered implant, Biomet 3i) was inserted. A connective tissue graft was harvested from the palate and positioned to ensure that it would cover the alveolar ridge both buccally and below the incision line. Thus, single sutures were placed for stabilization of the crestal incision edges. After 5 months of healing, the ridge dimensions were preserved and slightly improved both horizontally and vertically. The implant was uncovered and an impression was made for the preparation of an implant-supported provisional restoration with the desired emergence profile (Fig 9). After 4 months, another impression was taken and the final restoration

Figs 8a and 8b Preoperative situation: *(a)* clinical view and *(b)* radiograph.

was cemented. The 2-year follow-up revealed good soft tissue stability (Fig 10).

DISCUSSION

The alveolar processes in the jaws are tooth-dependent structures that will undergo significant structural changes whenever the teeth are lost.[7] Nevertheless, if ridge collapse can be prevented or minimized after tooth extraction, more predictable outcomes with superior esthetics can be accomplished along with fewer surgical procedures.

The dilemma that clinicians face is how to manage tooth extractions to provide for the future placement of a dental implant or to maximize ridge dimensions for the fabrication of a fixed prosthesis. If performed inadequately, the resulting deformity can be a considerable obstacle to the esthetic, phonetic, and functional results that both our patients and we clinicians expect at this current time. Although the bone resorption continues over time, the most statistically significant loss of tissue contour occurs during the first month after tooth extraction and can average up to 3 to 5 mm in width by 6 months.[33]

Placing a graft material into a socket has been one proposed method of preserving the natural tissue contours at extraction sites for possible reconstruction with an implant-supported prosthesis.[34] As implants serve as an aid for prosthetic devices, they need to be placed in a three-dimensionally perfect location to achieve the appropriate esthetic, phonetic, and functional demands of the patient. This is particularly important in the esthetic zone where the gracile natural contours of the periodontium are quite evident and their absence can be devastating.[35] To optimize the marginal gingival architecture and implant positioning, socket seal surgery has been advocated as either a combined procedure with immediate and early implant placement or with socket preservation procedures to help to stabilize soft tissue margins of the socket at the initial healing phase (2 to 4 weeks).

Vignoletti et al[6] looked at surgical protocols for ridge preservation after tooth extraction. The conclusion of this article suggested that the potential benefit of socket preservation therapies was demonstrated, as these procedures resulted in significantly less vertical and horizontal contraction of the alveolar bone crest. However, the scientific evidence did not provide clear guidelines with regard to the type of biomaterial or surgical procedure to best achieve ridge preservation.

Hämmerle et al[2] summarized the evidence-based knowledge on the biology and treatment of extraction sockets based on the reviews performed for the Sixth Expert Meeting: Evidence-Based Knowledge on Biology and Treatment of Extraction Sockets Including the Placement of Dental Implants.[2] Their review of the meta-analyses that were performed in preparation for this conference indicated the alveolar ridge undergoes a mean horizontal reduction in width of 3.80 mm and a mean vertical reduction in height of 1.24 mm within 6 months after tooth extraction without ridge preservation therapies. Regarding the various materials applied

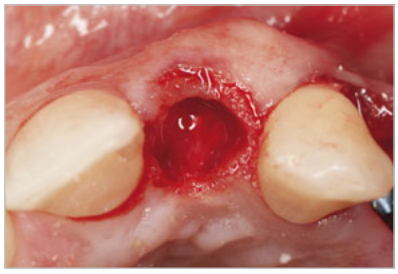


Fig 9a After extraction and thorough debridement, the bone walls were examined.

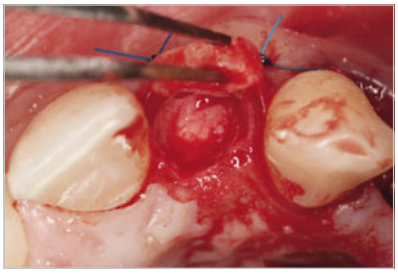


Fig 9b First, the graft was stabilized with two interrupted sutures on the buccal margins of the socket. The xenograft was packed into the socket and a collagen plug was inserted to provide some support to the sealing graft.

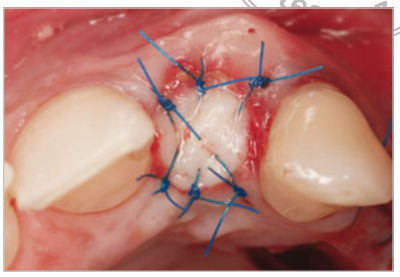


Fig 9c The free gingival graft was sutured to the recipient site.

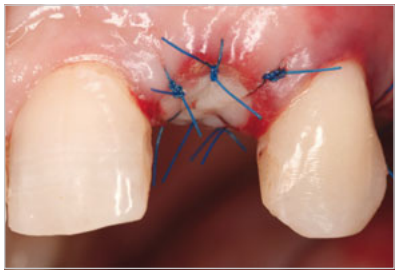


Fig 9d The recipient site margins showed signs of mild inflammation.

Fig 9e Radiographic assessment confirmed the complete fill of the socket and periapical lesion cavity.

Fig 9f A provisional bonded restoration was adjusted to fit passively onto the grafted site.

Fig 9g After a healing period of 6 months, some horizontal as well as vertical bone resorption and ridge remodeling were evident.

Fig 9h Healing at 6 months (anterior view).

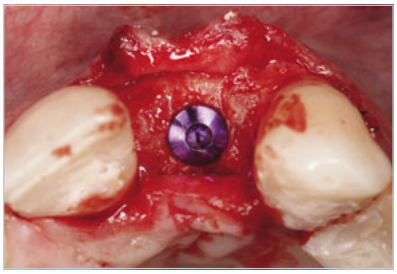


Fig 9i The tapered implant was inserted in an optimal three-dimensional position.

to retain alveolar ridge width evaluated in the clinical studies, the systematic reviews did not show significant differences except for the collagen plug alone, which revealed negative results. Moreover, the group advocated that to maximize maintaining ridge volume following tooth extraction, one should consider raising a flap, placing a biomaterial with a low resorption/replacement rate, and trying to obtain primary wound closure.

It would appear of paramount importance to reproduce anatomical characteristics of the transmucosal portion of the abutment-crown complex to achieve natural looking peri-implant mucosa integration. Understanding the dimensional changes at the peri-implant mucosa level for single implant crowns in the anterior maxilla is essential to achieve esthetic integration. In this context, socket seal surgery can be considered as a technique for "soft tissue stabilization" at the marginal area of the extraction socket, and compensate

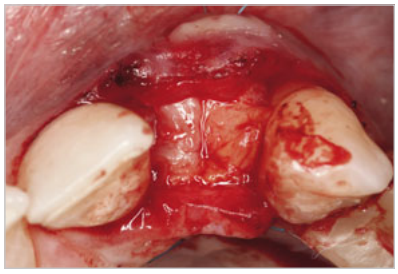


Fig 9j The connective tissue graft was secured to the buccal flap and to the palatal aspect with horizontal mattress sutures.

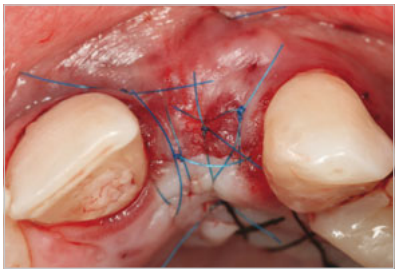


Fig 9k Closure was completed with interrupted sutures.

Fig 9l After 5 months of healing, the ridge dimensions were improved both horizontally and vertically.

Fig 9m A straight healing abutment was inserted after uncovering procedure (the use of a narrow abutment maximizes space for soft tissue).

Fig 9n The implant-supported provisional restoration was fitted at this stage.

Fig 9o An appropriate transition zone was obtained for the final impression and the preparation of an all-ceramic crown after 4 months of healing.

Fig 10a The 2-year follow-up revealed soft tissue stability. However, some bone loss was clearly evident, undermining the likelihood of a complete distal papilla at the end of the treatment.
Fig 10b The occlusal view shows some horizontal deficiency
Fig 10c Radiographic assessment revealed some crestal bone loss at mesial and distal aspects.

for the defects that form following tooth extraction. If the pretreatment conditions are not ideal, a multistage approach to defect reconstruction is needed to achieve a predictable treatment outcome, even though this places a greater burden on the patient. Socket seal surgery may be performed in these cases, regardless of whether an immediate, early, or delayed implant is planned. This will allow more predictable treatment results under non-ideal starting conditions, achieving acceptable stabilization of the peri-implant soft tissues and minimal changes around the final restoration.

Jung et al[36] evaluated radiologically different techniques for ridge preservation. This study demonstrated that the application of collagenized DBBM (DBBM-C) into the extraction socket, covered with either a collagen matrix (CM) or an autogenous soft tissue punch graft (PG), resulted in significantly less vertical and horizontal resorption compared with the control group in the majority of the assessed parameters 6 months after tooth extraction. The application of a slowly resorbing grafting material (DBBM + 10% collagen) covered either with a collagen matrix (CM) or a PG resulted in a reduced amount of vertical bone loss at the buccal and the lingual aspect. In this study, the vertical changes have been analyzed on the level of the bone plate and on the level of the most coronal point of the graft material. The results from the graft materials demonstrated that it was not possible to mineralize the amount of graft material at the most coronal portion of the graft material. However, part of the vertical bone loss of the plates could be partially compensated or even improved by using the DBBM-C material.

This was predominantly evident in the PG group revealing a gain of the reduced bone plates of up to 1.2 mm at the buccal aspect. This observation corroborates histologic outcomes of a clinical study using either hydroxyapatite/tricalcium phosphate (HA/TCP) or DBBM following tooth extraction.[37]

Another consecutive study[38] reports the clinical volumetric data of the same randomized, controlled, clinical investigation. This study was performed to compare the effect of different techniques for ridge preservation with spontaneous healing on a soft tissue contour level. After 6 months, spontaneous healing showed the most pronounced reduction of the labial ridge contour. This finding is in accordance with a recent study which showed that alveolar ridge preservation using xenogenic bone substitute (prehydrated collagenated cortico-cancellous porcine bone) with or without a free gingival graft was not able to entirely compensate for the alveolar ridge reduction. Covering the orifice of the extraction socket using a free gingival graft, with or without application of a filler material, the postoperative external contour shrinkage could be somewhat limited.[18] This study showed a similar trend. Again results were statistically significant, favoring sites with a ridge preservation approach. Compared to the soft tissue alterations in this study, more distinct differences could be found on a bone level. Therefore, soft tissue changes do not seem to completely follow the changes at the alveolar bone level, as recorded in the same patients from the previous study.[36]

It appears that primary closure of the wound is beneficial regarding the volume gained applying this approach. Although primary wound closure was generally considered an important factor for success, the literature did not allow a meaningful comparison of different techniques for primary wound closure (soft tissue punch, connective tissue graft, barrier membrane, soft tissue replacement matrix).[2,6]

Gholami et al[39] studied human extraction sockets grafted with either a synthetic or bovine form of HA. In their study, nonmolar teeth were extracted and studied in a split-mouth design. There were no control sites that were treated without graft and barrier protection. Additionally, all sites were protected with both a resorbable barrier and primary closure. As previously stated, elevating flaps at the time of extraction could have led to some portion of the 14% site collapse that was reported on average at the 6- to 8-month reentry time point. Full-thickness flaps were elevated at the reentry, which could lead to further bone loss around the newly placed dental implants.[40] The socket seal procedure would contribute to obtaining primary wound

closure and to performing minimal flap elevation at the time of early or delayed implant placement and a less aggressive surgical procedure.

Implants placed into the fresh extraction sockets do not prevent the resorption of the alveolar bone. Although osseointegration is achieved in the early stage, modeling of the bone may cause this level to recede apically.[5] To minimize this remodeling process, additional techniques such as socket seal surgery should be introduced in these protocols, to minimize the dimensional changes in the marginal part of the socket.

The socket seal surgery cannot completely compensate the tissue shrinkage that occurs following tooth extraction, but it optimally enhances the starting conditions for implantation in combination with hard and soft tissue augmentation when early or delayed protocols are planned, and improves the conditions when the stage-two surgery is performed after an immediate placement protocol.

Stability, integration, and color matching of the graft into the natural surrounding tissues appear to be acceptable from an esthetic point of view. According to the authors´ experience, the technique is considered as technical skill sensitive, increasing the treatment time and number of procedures. Moreover, considering the existence of a donor site, patient's morbidity cannot be underestimated.

The recurring theme was that there was considerable heterogeneity to study designs, time periods, and methods of evaluation. This created great difficulty in trying to answer with good high-quality evidence questions about the techniques and materials to be used for maximizing regeneration at the time of tooth extraction or in which situations this ought to be used. However, multiple studies demonstrated less ridge resorption when alveolar ridge preservation procedures were used versus the placement of no graft material in fresh alveolar sockets.[41]

The scientific evidence from all of these systematic reviews seems to suggest that socket preservation techniques are of some benefit with regard to reducing horizontal loss of the alveolar ridge. Whether this is consequential for the placement of a dental implant using a delayed approach, whether the results to such care hold up long term, whether this becomes more critical as the buccal plate becomes thinner, and which technique and/or material might provide the best results are still questions that require clarification. Clearly, if bone width is of importance, then grafting the socket at the time of extraction may be important.[41] Thus, socket seal surgery can be beneficial at this stage.

The meta-analysis by Morjaria et al[42] showed that no clear conclusions can be drawn from the numerous studies in the literature. Many of the grafted sites evaluated in the articles referenced in this review had remnants of the graft materials in histologic samples. If the grafting material resorbs and is converted to vital bone too quickly, the site may exhibit increased vertical and/or horizontal collapse of the alveolar socket. If the grafting material resorbs too slowly, the site may exhibit reduced amounts of vital bone formation. The surgeon who is performing extraction therapy must be aware of the physical and physiologic interactions of the host environment with any graft and/or barrier inserted at the time of extraction.[41] In this context, socket seal surgery would help to stabilize a blood clot and create an accurate environment for the bone regeneration process.

CONCLUSION

Socket seal surgery seems to be an effective technique to optimize soft tissue conditions for implant insertion and augmentation procedures, and compensate the volumetric changes in the alveolar ridge at least to a certain extent when immediate, early, or delayed placement protocols are utilized for single tooth replacement. This technique should be considered as a useful tool which presents advantages on maintaining good ridge architecture and soft tissue stability around the final restoration. However, careful case selection is essential to achieve an optimal esthetic outcome.

Finally, the literature has shown that although some degree of bone modeling and remodeling will occur

after tooth extraction, different ridge preservation procedures resulted in significantly less vertical and horizontal contraction of the alveolar bone crest. However, the outcomes could not indicate the type of surgical procedure or biomaterial that is most suitable for this clinical indication, although the use of barrier membranes, a flap surgical procedure, and full flap closure demonstrated better results. Moreover, there are limited data on the possible influence of these therapies on the long-term outcomes of implant therapy.

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