DENTAL AND MEDICAL JOURNAL - REVIEW

e-ISSN 2667-7288 **Vol** 3, **Issue** 3, (2021) *Review Article / Derleme Makale*

AN UP-TO-DATE TECHNIQUE FOR PRESERVING ALVEOLAR SOCKET: SOCKET SHIELD TECHNIQUE

ALVEOLER KRETİ KORUMAYA YÖNELIK GÜNCEL BİR TEKNİK: SOKET KALKANI TEKNİĞİ

Ezgi CEYLAN[1], Ezgi GÜRBÜZ[2]

[1] Res. Asst., Department of Periodontology, Faculty of Dentistry, Kutahya Health Sciences University, Kutahya/TURKEY

ORCID ID: 0000-0003-1835-0474

[2] Asst. Prof., Department of Periodontology, Faculty of Dentistry, Kutahya Health Sciences University, Kutahya/TURKEY

ORCID ID: 0000-0001-8774-8537

Corresponding Author:

Res. Asst. Ezgi CEYLAN,

Department of Periodontology, Faculty of Dentistry, Kutahya Health Sciences University, Kutahya/Turkey,

ezgi.ceylan@ksbu.edu.tr , +90 274 265 22 69

Article Info / Makale Bilgisi

Received / Teslim: January 10, 2021
Accepted / Kabul: October 28, 2021
Online Published / Yayınlanma: October 31, 2021
DOI:

Ceylan E, Gürbüz E. An up-to-date technique for preserving alveolar socket: socket shield technique. Dent & Med J - R. 2021;3(3):1-14.

DENTAL AND MEDICAL JOURNAL - REVIEW

e-ISSN 2667-7288 **Vol** 3, **Issue** 3, (2021) ***Review Article / Derleme Makale***

Abstract

Adequate alveolar bone volume and appropriate bone architecture should be present for the treatment of tooth loss with dental implant-supported restoration in the anterior maxillary aesthetic region. Therefore, a number of techniques such as atraumatic extraction, socket augmentation, guided bone regeneration, socket seal technique and immediate implantation are recommended in this region to prevent alveolar bone resorption and preserve bone dimensions for ideal functional and aesthetic rehabilitation. Although these techniques show significant effects in preserving the alveolar bone, a technique in which the alveolar socket can be fully protected is not yet available. Loss of the periodontal ligament and associated vascular support seems to be the cause of resorption, and therefore, the Socket Shield Technique, in which part of the periodontal ligament is protected by the root fragment remaining in the socket, has been described to prevent physiological bone resorption. According to the studies, it was concluded that this new technique can be used to preserve hard and soft tissue in the anterior maxillary aesthetic region. However, prospective studies with a large number of patients and long-term follow-up are needed for it to be accepted as conventional immediate implantation in clinical practice.

Keywords: *Alveolar ridge preservation, socket shield technique, root membrane technique, partial extraction therapies, immediate implant placement.*

Özet

Maksiller anterior estetik bölgede diş eksikliğinin dental implant destekli restorasyonlarla tedavisinde yeterli alveoler kemik hacminin ve uygun kemik mimarisinin olması gerekir. Dolayısıyla bu bölgede ideal fonksiyonel ve estetik rehabilitasyon için diş çekimi sonrası gelişen alveoler kemik rezorbsiyonunu engelleyecek ve kemik boyutlarını idame ettirebilecek birtakım teknikler (atravmatik çekim, soket ogmentasyonu, yönlendirilmiş kemik rejenerasyonu, soket seal tekniği ve immediat implantasyon gibi) önerilmektedir. Bu teknikler çekim sonrası alveoler kemiği rezorbsiyondan korumada belirgin etkiler gösterseler de alveoler soketin tamamen korunabildiği bir teknik henüz mevcut değildir. Diş çekimiyle birlikte periodontal ligament ve ilişkili vasküler desteğin kaybedilmesi rezorbsiyonun bir sebebi olarak görülür ve bu nedenle çekim sonrası tetiklenen fizyolojik kemik rezorbsiyonundan kaçınmak adına periodontal ligamentin bir kısmının soket içerisinde bırakılan kök fragmanı ile korunduğu Soket Kalkanı Tekniği tanımlanmıştır. Yapılan çalışmalara göre bu yeni tekniğin maksiller anterior estetik bölgede kemik dokusunu ve yumuşak dokuyu koruma amacıyla kullanılabileceği sonucuna varılmıştır. Ancak klinik pratikte geleneksel immediat implantasyon gibi kabul görmesi için hasta sayısının fazla olduğu, uzun dönem takipleri olan prospektif çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: *Kret koruma, soket kalkanı tekniği, kök membran tekniği, parsiyel ekstraksiyon terapileri, immediat implantasyon.*

DENTAL AND MEDICAL JOURNAL - REVIEW

e-ISSN 2667-7288 **Vol** 3, **Issue** 3, (2021) *Review Article / Derleme Makale*

OVERVIEW / GENEL BAKIŞ

Alveolar bone resorption following tooth loss has been clearly stated in the literature (1-4). After tooth extraction, periodontium shows atrophy resulting in complete loss of attachment involving cementum, periodontal ligament and bundle bone. This resorption process results in a narrower and shorter alveolar crest(5). The dimensional change of buccal alveolar crest is greater than that of the lingual. The bone resorption, clearly seen on the buccal crest, has been attributed to the rapid loss of the bundle bone, which is often not accompanied with lamellar bone in the coronal part of buccal crest (1).

Considering the importance of aesthetics for dental implant treatment, alveolar crest resorption after tooth extraction poses a serious problem, especially for anterior maxillary region. Therefore, alveolar crest preservation techniques including socket augmentation, guided bone regeneration (GBR) and socket seal technique have been recommended to maintain alveolar bone dimensions (6-10). However, these techniques seem to be insufficient to compensate for the dimensional change after tooth extraction (11). It was reported that these techniques cause high rates of complications (eg. edema, facial pain and erythema) and some of the graft materials unfavorably affect normal healing process (12, 13). Immediate implant placement, another surgical procedure preferred to avoid resorptive process, was also stated to show marked resorption in buccal and palatal bone walls four months after implant placement(14). In conclusion, although all of the mentioned techniques show significant effects compared to natural socket healing, there is not yet a technique in which the alveolar socket can be completely preserved(15).

Loss of periodontal ligament and associated vascular support is thought to contribute to the resorptive process(1, 16). Due to loss of ligament; the bundle bone vascularized by the vessels originating from the ligament cannot be adequately nourished and as a result it is resorbed. Therefore, it was argued that root fragment left in the socket can protect periodontal attachment and thus alveolar bone.

Early studies on this subject have suggested that leaving the root of hopeless tooth in the socket protects alveolar bone(17-19). Malmgren et al. described decoronation technique by preserving the roots of ankylosed teeth in the bone. With this technique, it was observed that existing bone volume was maintained, and there was even a vertical bone growth in the coronal part(19). The next technique, namely root submergence technique, in which decoronated roots are covered with soft tissue graft, was stated to be effective in protecting the tissue and aesthetics in the pontic area of restorations(20).

The structural difference between dental implant and tooth, attributed to the lack of periodontal ligament, led researchers to study whether a periodontal attachment-like tissue, different from osseointegration, could be formated at the implant-bone interface. For this purpose, implants were placed in contact with root fragments in several studies(21-23). Buser et al.(21, 22), placed hollow cylinder implants in contact with apical root portions of monkeys. In the histological sections, it was observed that new cementum, collagen fibers positioned towards the implant surface and periodontal ligament were formed after 12 months in the area where root fragment was in contact. It was also pointed to the presence of osseointegration on the implant surface which was not in contact with the retained root fragment. In another study on this topic, a cylindrical

e-ISSN 2667-7288 Vol 3, Issue 3, (2021) Review Article / Derleme Makale

dentin chamber was created by hollowing the roots to a depth of 5 mm and leaving thin dentinal wall(23). Vertical slits were also prepared for periodontal ligament cells to reach the implant site. However, unlike the previous study, implants were not placed in contact with the root dentin and a wide gap was left between the implant and root fragment. Following four months of healing, it was shown that cementum and periodontal ligament were formed on the implant and root surface, also new bone was formed at the implant-root interface. But, it was determined that the newly formed bone did not have direct contact with the implant and root, there was a connective tissue barrier in between, and most of the implants healed through fibrous encapsulation. Gray and Vernino(24), on the other hand, placed implants in the areas where the root fragments were retained, similar to the study of Buser et al(21, 22). They stated that there was no fibrous encapsulation, and the root fragments did not compromise the implant function in any way. It was concluded that human studies on the presence of periodontal ligament at the implant-root interface are needed. Though, it is ethically not possible to perform these studies in humans. However, in the histological examination of an implant placed inadvertently in contact with the retained root and afterwards extracted due to peri-implantitis, not originating from the root fragment, the presence of cementum was only detected on the implant surface in contact with the root(25).

1. Socket Shield Technique

Hürzeler et al.(15) described Socket Shield Technique (SST) in which a part of periodontal ligament is preserved in order to avoid physiological bone resorption triggered after tooth extraction. In this experiment, mandibular third and fourth premolar teeth of a beagle dog were separated by hemisection and distal aspect of the root was decoronated. Following implant osteotomy on the lingual part of the root, buccal root fragment was prepared approximately 1 mm coronal to the buccal crest. After applying enamel matrix derivate (EMD) to the inner surface of the buccal fragment, two implants were placed in direct contact with the fragment and another two were placed without contact. In the results of histological examination performed four months later, no inflammatory response was observed in any of the implants, and it was found that periodontal ligament was intact and osseointegration was observed in the lingual part. When the implants placed without contact were examined, new cementum was formed on the root surface with increasing thickness towards apically and a healthy connective tissue up to 0.5 mm was present at the implant-root interface. On the other hand, the presence of cementum on the root and implant surface was detected without soft tissue at the interface of implants placed in direct contact with the fragment.

e-ISSN 2667-7288 Vol 3, Issue 3, (2021) Review Article / Derleme Makale

The indications and contraindications of SST are represented in Table 1.

Table 1.
The indications and contraindications of SST

Indications	Contraindications
Unrestorable tooth that require immediate implant placement	External or internal resorption affecting buccal part of the root
Vital or devital tooth	Seriously damaged tooth with caries below bone level
Tooth with or without apical pathology	Horizontal fracture below bone level
Periodontally healthy tooth	

1.1. Technical Aspects

Hürzeler et al.(15), as described above, removed the lingual root part from the socket after implant osteotomy and finally inserted the implant. However, researchers who later applied the technique and defined it with different names such as Partial Extraction Therapies(26) and Root Membrane Technique(27), separated the root and performed implant osteotomy after removing the palatinal/lingual part (Fig. 1).

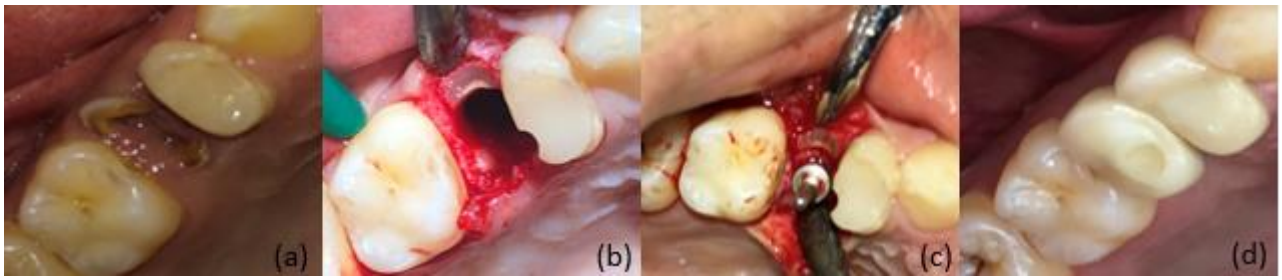

Figure 1. *Preparation steps of the technique.*

When SST was first described, it was applied with flapless surgery(15). However, Kher(28) suggested that both flapless and conventional flap approaches can be applied with this technique. Although flapless surgery has the advantage of preventing resorption by maintaining periosteal blood flow, it was reported that conventional flap approach can be implemented in cases where the surgical area is limited and the clinician's experience is insufficient.

Although authors of the technique supported the preparation of the buccal root fragment/shield at 1 mm coronal to the crest to protect dentogingival fibers, other researchers stated that it should be prepared at the crest level to prevent internal or external shield exposure that may develop after the procedure(29).

e-ISSN 2667-7288 Vol 3, Issue 3, (2021) Review Article / Derleme Makale

In the literature, yet, there is no consensus on whether the gap between shield and implant should be grafted or not. Gluckman(30) suggested that graft application should be performed in large gaps. It was also recommended in cases where the gap is more than 3 mm(31).

Hürzeler et al. suggested the application of EMD to promote periodontal attachment formation; but as the bone growth between the root dentine and implant was histologically demonstrated without EMD administration(32), this step was abandoned in subsequent studies.

There is a heterogeneity in the literature regarding shield thickness. Gluckman et al.(29) suggested that shield should be prepared at half thickness of the distance between root canal and buccal fragment. It was also argued that it should be prepared with a thickness of at least 1-1.5 mm against fracture risk(27, 33).

In an animal study in which the effect of height and thickness of root segments on bone resorption was analyzed, it was concluded that the thickness affects bone resorption rather than the height and resorption decreases as thickness increases(34).

There is also no consensus in the literature regarding shield length. Although Calvo-Guirado et al.(35) advocated that shield should be kept short in order to have a large amount of bone that implant would be in contact, Kumar and Kher(31) emphasized that it should be approximately two-third of root length or at least 8 mm. In addition, as shield may be mobilized if it is too short, it was recommended that a long shield may be prepared as long as the apex of the root is removed(36).

1.2. Modifications of the Technique

The technique has been modified over time since it was introduced. Gluckman et al.(26) used the term "Partial Extraction Therapies" (PET), which represents all interventions to prevent crest collapse. They described these interventions as root submergence technique, SST and pontic shield technique. Pontic shield technique(37) is a modification of SST and is recommended for pontic areas where root submergence technique cannot be applied due to apical pathology. The technique is similar to SST in terms of shield preparation, but after shield preparation, a bone graft is applied to the socket and finally a membrane or soft tissue graft is recommended to cover the area.

Kan and Rungcharassaeng(38) described the proximal SST to maintain interdental papilla between the implants in the anterior region. In this technique, the shield is prepared in the proximal area of the tooth adjacent to implant-supported restoration, followed by immediate implant placement and temporary restoration. It was stated that satisfactory aesthetic results may be obtained by implementing this technique.

Glocker et al.(39) applied a modified SST by applying a collagen cone to the socket after the shield was prepared and placing the implant six months later. They claimed that the alveolar bone was preserved in this method.

SST is recommended for anterior teeth that cannot be restored and require immediate implant placement. However, this technique was also applied to the immediate molar implant sites to preserve the alveolar

e-ISSN 2667-7288 Vol 3, Issue 3, (2021) Review Article / Derleme Makale

crest(40). Nevertheless, SST is not recommended for posterior and mandibular anterior teeth with short and curved roots, as shield preparation may be difficult.

1.3. Histological Examinations

In a beagle dog study, implants were placed in direct contact with vertically separated buccal root segments(32). After four months of healing, histological analysis showed that buccal tooth fragment was attached to the bone by periodontal ligament without resorption activity and osseointegration occurred on the lingual aspect. New bone formation was also observed on the vertical line and between root dentine and implant. The bone formation at implant-root interface was attributed to not applying EMD to the root surface. As a result, it was concluded that besides its aesthetic advantage, SST is a low cost treatment due to no need for graft and membrane application. In addition, it was shown that SST can be modified in vertically fractured teeth.

An implant placed unplannedly in contact with the retained root was diagnosed as peri-implantitis and decided to be extracted(41). The extracted implant was examined histologically and consequently bone tissue was observed between the root dentine and osseointegrated implant surface. It was found controversial that the root may be the cause of peri-implantitis, because the bone loss was far from the root fragment. However, the authors argued that peri-implant bone health could have been maintained if the root had been prepared in accordance with the technique.

Siormpas et al.(16) preferred to name the technique "Root Membrane Technique" (RMT), because it was thought that periodontal ligament functions like a membrane. A patient had underwent immediate implant placement with RMT five years before a traffic accident(42). Because of the accident, it was deemed necessary to remove a small maxillary bone fragment including the implant, due to the fractures in the craniomaxillofacial region, and thus histological examination of the implant with surrounding intact tissues was performed. As a result of the examination, the presence of dense compact bone was observed, especially in the apical and middle third of the implant. There was no resorptive activity in the buccal bone and the periodontal ligament was found to be intact. In addition, it was determined that cementum migration from the root fragment towards the implant surface was present in the apical third.

The limited number of human case reports has yielded similar histological results to animal studies. In order for this technique to be considered as a socket preservation technique, the characteristic of tissue formed at the implant-root interface and the issue whether required tissue will be cementum or bone should be clear. However, sufficient information to answer these questions is not yet available in the literature.

1.4. Clinical Studies

Prospective, randomized controlled trials comparing this technique with conventional immediate implant placement have recently been published(43-45). In these studies, early results of the technique have

e-ISSN 2667-7288 Vol 3, Issue 3, (2021) Review Article / Derleme Makale

been reported. A limited number of retrospective studies examining clinical effects of the technique in the long term is also available in the literature(16, 27, 46-48).

In a randomized controlled study in which SST was compared with conventional immediate implantation technique, marginal bone level was evaluated with intraoral radiographs taken at baseline, post-operative third month, and post-operative third year(44). In addition, Pink Esthetic Score (PES) was evaluated with intraoral photographs taken during the same follow-up periods. As a result of analysis, marginal bone resorption was observed at a lower rate in SST group and also higher aesthetic scores were obtained in SST group.

In another controlled trial, comparing marginal bone loss of 26 implants applied with SST and conventional immediate implantation technique, radiological evaluations were carried out for two years(43). At the end of the follow-up period, a bone loss of 12% corresponding to 5 mm was observed in conventional implantation group, while the rate in SST group was 2% corresponding to 0.8 mm. Marginal bone loss was foud to be significantly higher in conventional immediate group.

In a study of Bäumer et al.(48), two impressions were taken before tooth extraction and post-operative fifth year, from ten patients who underwent immediate implant surgery performed with SST in anterior maxillary region. Three-dimensional (3D) scans of plaster models were digitally overlapped and the change in facial peri-implant tissue contours and the amount of soft tissue retraction were compared. As a result of the study, it was claimed that SST achieved good aesthetic results that preserve facial tissue contours with a less invasive surgery.

Sun et al.(45) compared SST and conventional immediate implant placement by examining baseline and post-operative sixth month Cone Beam Computed Tomography (CBCT) images, and found that buccal bone height and width values of conventional group on sixth month were lower than SST group while there was no difference between groups at baseline. In addition, digital photographs obtained from the impressions taken preoperatively and at the 6^{th}, 12^{th} and 24^{th} months postoperatively were evaluated in terms of PES. As a result, although higher values were obtained on 24^{th} month in SST group, there was no statistically significant difference between groups in any time period.

In another study, comparing conventional immediate implantation and SST in anterior maxillary region by means of CBCT examination, it was found that significant less resorption was observed in the buccal bone in SST group and the authors stated that SST can be performed in cases where the buccal bone is less than 1 mm(49). At the same time, patient satisfaction was evaluated by the analysis of visual analog scale and SST group showed higher values compared with conventional group.

A retrospective study, including 128 patients who underwent immediate implantation with SST and were followed up for more than one year, found 96.1% implant survival rate(47). It was also stated that complications such as infection, shield exposure, shield migration were seen and these complications (25 implants-19.5%) were successfully treated. As a conclusion, the survival and complication rate were found to be comparable with those obtained in conventional delayed and immediate implant placement.

Immediate implant placement with RMT and immediate temporary restorations were performed in a retrospective study involving 46 patients(16). After an average of 40-month follow-up period, 100% implant

e-ISSN 2667-7288 Vol 3, Issue 3, (2021) Review Article / Derleme Makale

survival rate was obtained. In only one case, resorption was observed at the apical part of the root fragment, which did not cause any complications in implant osseointegration and was followed up without any intervention.

A study in similar design followed 250 implants, immediately placed with RMT, over a period of 10 years(27). As a result, after an average follow-up period of 49.94 months, implant survival rate was reported as 97.3%. However, five implants failed during the follow-up period and biological complications (infection and migration of the root fragment, peri-implant mucositis, peri-implantitis) were seen in eight cases. The authors stated that since the incidence of complications is relatively low, RMT can be applied as a reliable technique in the long term.

Few clinical studies have mentioned complications and necessary interventions(16, 27, 47). It was reported that shield exposure is the most common complication(47). In cases where exposure is internal, namely towards restoration, either exposed part should be followed without intervention, or reduction of exposed part with a diamond bur should be performed. In the presence of external exposure, that is towards oral cavity, a connective tissue graft is recommmended to cover the exposed surface in addition to the reduction. If shield has infection and mobility, shield removal and GBR should be applied as long as there is no infection in the implant site. Otherwise, the implant should be extracted. In addition, the conditions such as shield migration and asymptomatic resorption in the apex of the shield, detected on radiographs, may be followed without any intervention (27, 47).

A systematic review, examining SST in terms of its biological plausability and long-term clinical prognosis, evaluated animal studies, human case reports and clinical studies (50). Although there was no homogeneity between studies, statistical analysis was performed in terms of complications and adverse effects. Furthermore, periodontal ligament and cementum formation were reported as complications in the review. The studies (23, 35), in which SST was reported to cause a high rate of complications, were found to perform different root configurations not related with SST. However, the authors stated that SST may be technique-sensitive, considering the studies (16, 48) which performed shield preparation of the SST and had favorable results in long term. Nevertheless, it was reported that the shield, prepared within the framework of a specific technique, may also create a risk, as the roots left inadvertently cause complications such as infection and bone loss in the implant site (25, 51-53).

Another systematic review, concerning the effect of SST on the stabilization of facial gingival and osseous architecture, investigated clinical and animal studies, most of which are case reports (54). The authors argued that the implant failure and complication rate were less than in previous review (50) and the increased rate in the previous review was due in part to the modification of SST in one study (55). It was concluded that although a few studies with long follow-up period and increased sample size yielded promising results, this technique should be used with caution in clinical practice until a higher level of evidence is established. Blaschke and Schwass (56) also provided similar results in their recently published systematic review.

e-ISSN 2667-7288 Vol 3, Issue 3, (2021) Review Article / Derleme Makale

SUMMARY / SONUÇ

According to the literature, SST may have the capability to preserve hard and soft tissue in the anterior aesthetic area. However, since it is a novel technique, there is an ambiguity regarding the histology of implant-root interface, long-term clinical results and procedural issues such as shield thickness, shield length and the need for grafting. To eliminate these uncertainties, well-designed prospective studies are needed. In addition, as different terms have been attributed to the same technique, there is a requirement for single terminology in order to systematically review this technique.

Acknowledgements / Teşekkür

References / Referanslar

1. Araujo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. J Clin Periodontol. 2005;32(2):212-218.
2. Cardaropoli G, Araujo M, Lindhe J. Dynamics of bone tissue formation in tooth extraction sites: an experimental study in dogs. J Clin Periodontol. 2003;30(9):809-818.
3. Pietrokovski J, Massler M. Alveolar ridge resorption following tooth extraction. J Prosthet Dent. 1967;17(1):21-27.
4. Schropp L, Wenzel A, Kostopoulos L, Karring T. Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study. Int J Periodontics Restorative Dent. 2003;23(4):313-323.
5. Pinho MN, Roriz VL, Novaes AB, Jr., Taba M, Jr., Grisi MF, de Souza SL, et al. Titanium membranes in prevention of alveolar collapse after tooth extraction. Implant Dent. 2006;15(1):53-61.
6. Horvath A, Mardas N, Mezzomo LA, Needleman IG, Donos N. Alveolar ridge preservation. A systematic review. Clin Oral Investig. 2013;17(2):341-363.
7. Wang H-L, Neiva RF. Socket augmentation: rationale and technique. In: El Askary Ael S, editor. Fundamentals of Esthetic Implant Dentistry. 1st ed., ABD: Wiley-Blackwell; 2008, p. 140-224.
8. Iasella JM, Greenwell H, Miller RL, Hill M, Drisko C, Bohra AA, et al. Ridge preservation with freeze-dried bone allograft and a collagen membrane compared to extraction alone for implant site development: A clinical and histologic study in humans. J Periodontol. 2003;74(7):990-999.
9. Bartee BK. Extraction site reconstruction for alveolar ridge preservation. Part 2: membrane-assisted surgical technique. J Oral Implantol. 2001;27(4):194-197.

e-ISSN 2667-7288 Vol 3, Issue 3, (2021) Review Article / Derleme Makale

10. Lekovic V, Camargo PM, Klokkevold PR, Weinlaender M, Kenney EB, Dimitrijevic B, et al. Preservation of alveolar bone in extraction sockets using bioabsorbable membranes. J Periodontol. 1998;69(9):1044-1049.

11. Fickl S, Zuhr O, Wachtel H, Stappert CF, Stein JM, Hurzeler MB. Dimensional changes of the alveolar ridge contour after different socket preservation techniques. J Clin Periodontol. 2008;35(10):906-913.

12. Fiorellini JP, Howell TH, Cochran D, Malmquist J, Lilly LC, Spagnoli D, et al. Randomized study evaluating recombinant human bone morphogenetic protein-2 for extraction socket augmentation. J Periodontol. 2005;76(4):605-613.

13. Froum S, Cho SC, Rosenberg E, Rohrer M, Tarnow D. Histological comparison of healing extraction sockets implanted with bioactive glass or demineralized freeze-dried bone allograft: A pilot study. J Periodontol. 2002;73(1):94-102.

14. Botticelli D, Berglundh T, Lindhe J. Hard-tissue alterations following immediate implant placement in extraction sites. J Clin Periodontol. 2004;31(10):820-828.

15. Hurzeler MB, Zuhr O, Schupbach P, Rebele SF, Emmanouilidis N, Fickl S. The socket-shield technique: a proof-of-principle report. J Clin Periodontol. 2010;37(9):855-862.

16. Siormpas KD, Mitsias ME, Kontsiotou-Siormpa E, Garber D, Kotsakis GA. Immediate implant placement in the esthetic zone utilizing the "root-membrane" technique: clinical results up to 5 years postloading. Int J Oral Maxillofac Implants. 2014;29(6):1397-1405.

17. Guyer SE. Selectively retained vital roots for partial support of overdentures: A patient report. J Prosthet Dent. 1975;33(3):258-263.

18. O'Neal RB, Ground T, Levin MP, Carlos E. Submergence of roots for alveolar bone preservation: I. Endodontically treated roots. Oral Surg Oral Med Oral Pathol. 1978;45(5):803-810.

19. Malmgren B, Cvek M, Lundberg M, Frykholm A. Surgical treatment of ankylosed and infrapositioned reimplanted incisors in adolescents. Scand J Dent Res. 1984;92(5):391-399.

20. Salama M, Ishikawa T, Salama H, Funato A, Garber D. Advantages of the root submergence technique for pontic site development in esthetic implant therapy. Int J Periodontics Restorative Dent. 2007;27(6):521-527.

21. Buser D, Warrer K, Karring T. Formation of a periodontal ligament around titanium implants. J Periodontol. 1990;61(9):597-601.

22. Buser D, Warrer K, Karring T, Stich H. Titanium implants with a true periodontal ligament: an alternative to osseointegrated implants? Int J Oral Maxillofac Implants. 1990;5(2):113-116.

23. Parlar A, Bosshardt DD, Ünsal B, Çetiner D, Haytaç C, Lang NP. New formation of periodontal tissues around titanium implants in a novel dentin chamber model. Clin Oral Implants Res. 2005;16(3):259-267.

24. Gray JL, Vernino AR. The interface between retained roots and dental implants: a histologic study in baboons. J Periodontol. 2004;75(8):1102-1106.

25. Guarnieri R, Giardino L, Crespi R, Romagnoli R. Cementum Formation Around a Titanium Implant: A Case Report. Int J Oral Maxillofac Implants. 2002;17(5):729-732.

26. Gluckman H, Salama M, Du Toit J. Partial Extraction Therapies (PET) Part 2: Procedures and Technical Aspects. Int J Periodontics Restorative Dent. 2017;37(3):377-385.

27. Siormpas KD, Mitsias ME, Kotsakis GA, Tawil I, Pikos MA, Mangano FG. The Root Membrane Technique: A Retrospective Clinical Study With Up to 10 Years of Follow-Up. Implant Dent. 2018;27(5):564-574.

28. Kher U. Surgical Technique for Socket Shield Procedure. In: Kher U, Tunkiwala A, editors. Partial Extraction Therapy in Implant Dentistry. 1st ed., Switzerland: Springer; 2020, p. 17-42.

29. Gluckman H, Nagy K, Du Toit J. Prosthetic management of implants placed with the socket-shield technique. J Prosthet Dent. 2019;121(4):581-585.

30. Gluckman H (editor). Past, Present and Future of Partial Extraction Therapies. Hungary: University of Szeged; 2019 (PhD thesis).

31. Kumar PR, Kher U. Shield the socket: procedure, case report and classification. J Indian Soc Periodontol. 2018;22(3):266-272.

32. Baumer D, Zuhr O, Rebele S, Schneider D, Schupbach P, Hurzeler M. The socket-shield technique: first histological, clinical, and volumetrical observations after separation of the buccal tooth segment - a pilot study. Clin Implant Dent Relat Res. 2015;17(1):71-82.

33. Mitsias ME, Siormpas KD, Kontsiotou-Siormpa E, Prasad H, Garber D, Kotsakis GA. A Step-by-Step Description of PDL-Mediated Ridge Preservation for Immediate Implant Rehabilitation in the Esthetic Region. Int J Periodontics Restorative Dent. 2015;35(6):835-841.

34. Tan Z, Kang J, Liu W, Wang H. The effect of the heights and thicknesses of the remaining root segments on buccal bone resorption in the socket-shield technique: An experimental study in dogs. Clin Implant Dent Relat Res. 2018;20(3):352-359.

35. Calvo-Guirado JL, Troiano M, López-López P, Ramírez-Fernandez MP, de Val JEMS, Marin JMG, et al. Different configuration of socket shield technique in peri-implant bone preservation: An experimental study in dog mandible. Ann Anat. 2016;208:109-115.

36. Kulkarni S, Kumar T, Narayan T, Tunkiwala A. Errors and Complications in Partial Extraction Therapy. In: Kher, U. Tunkiwala A, editors. Partial Extraction Therapy in Implant Dentistry. 1st ed., Switzerland: Springer; 2020, p. 247-307.

37. Du Toit J. The pontic-shield: partial extraction therapy for ridge preservation and pontic site development. Int J Periodontics Restorative Dent. 2016;36:417-423.

e-ISSN 2667-7288 Vol 3, Issue 3, (2021) Review Article / Derleme Makale

38. Kan JY, Rungcharassaeng K. Proximal socket shield for interimplant papilla preservation in the esthetic zone. Int J Periodontics Restorative Dent. 2013;33(1):e24-e31.

39. Glocker M, Attin T, Schmidlin PR. Ridge preservation with modified "socket-shield" technique: a methodological case series. Dent J. 2014;2(1):11-21.

40. Schwimer CW, Gluckman H, Salama M, Nagy K, Du Toit J. The socket-shield technique at molar sites: A proof-of-principle technique report. J Prosthet Dent. 2019;121(2):229-233.

41. Schwimer C, Pette GA, Gluckman H, Salama M, Du Toit J. Human Histologic Evidence of New Bone Formation and Osseointegration Between Root Dentin (Unplanned Socket-Shield) and Dental Implant: Case Report. Int J Oral Maxillofac Implants. 2018;33(1):e19-e23.

42. Mitsias ME, Siormpas KD, Kotsakis GA, Ganz SD, Mangano C, Iezzi G. The Root Membrane Technique: Human Histologic Evidence after Five Years of Function. Biomed Res Int. 2017;2017:7269467.

43. Abadzhiev M, Nenkov P, Velcheva P. Conventional immediate implant placement and immediate placement with socket-shield technique–which is better. Int J Clin Med Res. 2014;1(5):176-180.

44. Bramanti E, Norcia A, Cicciu M, Matacena G, Cervino G, Troiano G, et al. Postextraction Dental Implant in the Aesthetic Zone, Socket Shield Technique Versus Conventional Protocol. J Craniofac Surg. 2018;29(4):1037-1041.

45. Sun C, Zhao J, Liu Z, Tan L, Huang Y, Zhao L, et al. Comparing conventional flap-less immediate implantation and socket-shield technique for esthetic and clinical outcomes: A randomized clinical study. Clin Oral Implants Res. 2020;31(2):181-191.

46. Mitsias MM, Bratos M, Siormpas K, Pikos MA, Kotsakis GA. Longitudinal Soft Tissue Changes During Periodontal Ligament-Mediated Immediate Implant Placement with the Root-Membrane Technique. Int J Oral Maxillofac Implants. 2020;35(2):379-385.

47. Gluckman H, Salama M, Du Toit J. A retrospective evaluation of 128 socket-shield cases in the esthetic zone and posterior sites: Partial extraction therapy with up to 4 years follow-up. Clin Implant Dent Relat Res. 2018;20(2):122-129.

48. Baumer D, Zuhr O, Rebele S, Hurzeler M. Socket Shield Technique for immediate implant placement - clinical, radiographic and volumetric data after 5 years. Clin Oral Implants Res. 2017;28(11):1450-1458.

49. Xu Y, Huang H, Wang L, Wu Q, Fu G, Li J. Comparison of clinical effects of a modified socket shield technique and the conventional immediate implant placement. Hua Xi Kou Qiang Yi Xue Za Zhi. 2019;37(5):490-495 (in Chinese with English abstract).

50. Gharpure AS, Bhatavadekar NB. Current evidence on the socket-shield technique: a systematic review. J Oral Implantol. 2017;43(5):395-403.

e-ISSN 2667-7288 **Vol** 3, **Issue** 3, (2021) ***Review Article / Derleme Makale***

51. Helsham RW. Some observations on the subject of roots of teeth, retained in jaws as a result of incomplete exodontia. Aust Dent J, 1959;5:70-77.

52. Herd JR. The retained tooth root. Aust Dent J. 1973;18(3):125-131.

53. Langer L, Langer B, Salem D. Unintentional Root Fragment Retention in Proximity to Dental Implants: A Series of Six Human Case Reports. Int J Periodontics Restorative Dent. 2015;35(3):305-313.

54. Mourya A, Mishra SK, Gaddale R, Chowdhary R. Socket-shield technique for implant placement to stabilize the facial gingival and osseous architecture: A systematic review. J Investig Clin Dent. 2019;10(4):e12449.

55. Troiano M, Benincasa M, Sánchez P, Guirado JC. Bundle bone preservation with Root-T-Belt: case study. Ann Oral Maxillofac Surg. 2014;2(1):7-12.

56. Blaschke C, Schwass DR. The socket-shield technique: a critical literature review. Int J Implant Dent. 2020;6(1):1-17