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Socket-Shield technique: Where do we stand today?

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ABSTRACT

Aim The aim of this systematic review is to present and analyze the available manuscripts that have developed the topic of socket shield technique and provide insights about the different emerging surgical protocols and their prognosis.
Materials and methods Randomized clinical trials, prospective cohort and retrospective studies were selected from the MEDLINE database (PubMed and OVID) up to December 2021 evaluating the surgical techniques as well as long term efficacy and prognosis of the socket shield technique.
Results Following the inclusion and exclusion criteria, 8 articles were eligible for the present study. In total 397 patients were treated using the socket shield technique, 6 articles presented a follow up of 5 years, one of 4 years and one of 10 years.
Conclusion Socket shield technique is a promising alternative after tooth removal in preventing post-extraction ridge alterations thus saving the pink and white esthetics score. However, the latter technique presents a highly sensitive surgical protocol that needs a skilled surgeon.

KEYWORDS Dental implants, Partial extraction, Root membrane, Ridge preservation, Socket shield.

INTRODUCTION

Implantology has noticeably evolved in recent decades and the use of dental implant to restore missing teeth is considered today as a reliable treatment option. This therapeutic choice helps provide biomimetic rehabilitation similar to the natural tooth's aesthetic details. However, placing an implant in the anterior zone is one of the most challenging situations regarding the prosthetic and surgical demands in this region (1). Therefore, today, besides the traditional demands for osseointegration objectives, peri-implant soft and hard tissue architecture is one of the leading aesthetic success parameters (2).
Such challenges are perceivable after extracting a hopeless tooth and replacing it with an implant due to the extraction socket's remodeling process. The lack of vascular supply from the periodontal ligament plays an essential role in the vertical and horizontal bone resorption, mainly the horizontal one, especially the buccal bone of the anterior maxillary teeth that is more at risk to resorption after tooth extraction (3). In addition to the modifications in the bone architecture following an extraction, the alveolus is affected due to the absence of soft tissue covering the socket, causing secondary intention healing. Soft and hard tissue post-extraction changes have been widely explained in the literature using several study casts, hence the critical role of socket preservation (4).
In recent years, numerous studies have addressed the importance of socket preservation in implantology using different terms such as socket preservation, ridge preservation, site preservation, and socket grafting (4,5,6). The technique of alveolar ridge preservation was formulated to reduce dimensional changes of the alveolar ridge post-extraction with the use of bone substitutes, biological products, membranes either alone or in conjunction with one another, whereas ridge augmentation aids in increasing the height or the width of the ridge (6). However, these techniques might decrease or limit the resorption of the ridge but can not prevent it. Similarly, a recent systematic review has demonstrated that immediate implant placement procedure plays a role in decreasing the socket postextraction resorption. However, the trauma caused by tooth extraction leads the clinicians to switch from the immediate implant placement protocol to the delayed one (7).
An alternative concept was introduced in the early 2010s

by Hürzeler et al., known as 'The Socket Shield Technique' (SST) applied first on animals and humans. The idea was to retain on the buccal side a part of the root section. The assumption was that leaving the tooth's root portion maintains the periodontal ligament and its vasculature that supply the bundle bone, consequently preventing the periodontium's collapse (8). The socket shield was performed 1 mm upon the crestal bone, and its length was around one-third of the root. The enamel matrix derivatives were neglected in some cases while inserting the implant facing the socket shield. However, there is still a lack of evidence regarding the use of these materials (8,9).

Later on, Gluckman et al. published several variations of this technique in which they explained the steps and instrumentations required to perform it (9, 10, 11). Many authors described this new approach as a predictable one to preserve the alveolar ridge, especially the buccal one, without bone remodeling increasing then the aesthetic outcome (9, 11, 12, 13). Nevertheless, complications can always happen. However, the new concept of partial extraction therapy, including the socket shield technique, is widely widespread today, yet some clinicians do not differentiate between them and their indications (14). Therefore, this narrative review aims to provide an overview of all the available literature to assess the socket shield technique's efficiency in the long term with the latest updates while assessing the author's perception of the different protocols described in the literature.

MATERIALS AND METHODS

An extensive search was conducted for studies published up to December 20, 2021; an electronic Medline (PubMed and OVID), Embase, and Cochrane Central search was performed, supplemented by a manual search, evaluating the long term efficiency of the socket-shield technique and describing each author's perspective when doing it.

Ultimately, removing reduplicates and subsequently using these terms for search procedures:

Subject: socket shield technique OR root membrane technique OR partial extraction therapy AND dental implant [all fields] AND adjectives: (buccal bone OR esthetic zone OR anterior zone OR extraction socket OR implant failure OR implant proximity to teeth OR implant in contact with root OR peri-implant bone preservation OR socket preservation [all fields].

The inclusion criteria were as follows.

- Randomized clinical trials and prospective cohort and retrospective studies.
- Implants deliberately placed close or in contact with buccofacial or proximal root segments to preserve the bone plate.
- Minimum follow-up two years post-loading.
- Studies elucidating only the socket shield or root membrane technique.
- Studies conducted on humans only.

The exclusion criteria were as follows:

- Systematic reviews, meta-analyses, and *in vitro* or preclinical studies.
- Studies that included patients taking medications or pathologies affecting bone metabolism.
- A follow-up less than two years post-loading.
- Studies not matching all the inclusion criteria.
- Studies on animals.

Studies were determined based on their title or abstract, including a full-text review for those studies that matched the inclusion criteria and checked eligibility. Finally, articles where the full text was absent or unpublished work where the authors were out of reach to give more information were removed. Patient, implant, and shield details were collected in tables, and a systematic review was conducted on the complications, radiographic, clinical, and aesthetic results.

RESULTS

After screening all the electronic studies from 2010 to December 2021 and referring to the inclusion and exclusion criteria, a total of 8 articles were reviewed carefully to extract the information needed about the efficiency of the socket-shield technique after a minimum of 2 years of follow-up post-loading. In total 397 patients were included in these studies who had undergone socket shield or root membrane technique to replace hopeless teeth, especially in the aesthetic area. The follow up post-loading was of 5 years in 6 studies (15-20), of 4 years in 1 article (10) and of 10 years in the last one (21). Tables show the patient's demographic information and different indications for the SST technique (Table 1), the surgical techniques and variations according to different authors (Table 2) and the complications, radiographic and clinical outcomes of the proposed technique (Table 3).

DISCUSSION

The purpose of this review was to assess the long-term clinical and radiographic outcomes of the socket-shield technique. The findings of the randomized controlled trials, prospective and retrospective studies with a minimum follow-up of 2 years showed the following.

- It is a promising technique with high aesthetic results but it is unfit for routine utilization, thus more studies are still required to evaluate the long-term effects.
- This technique associated with immediate provisionalization reduces buccal contour changes. It is effective in preventing post-extraction resorption of the buccal and bundle bone with ideal soft tissue stability in the aesthetic zone.
- This approach is safe promoting high implant success rate. It is an ideal procedure for the immediate implant

Study	Title	Nb patient	Patient gender	Age	Smoker	Periodontal disease	Indication	Technique
Baumer et al. 2017 (retrospective study)	Socket-Shield Technique for immediate implant placement–clinical, radiographic and volumetric data after 5 years	10	5 F 5 M	≥25	NO	None except apical pathology	A hopeless anterior tooth with intact neighboring teeth on the mesial and distal side	Socket-shield technique and immediate implantation
Hinze et al. 2018 (prospective case series)	Volumetric alterations around single toothimplants using the socket-shieldtechnique: preliminary resultsof a prospective case series	15	60% M 40% F	49.2 ± 11.9 years (range 22.4 to 65,98)	20 % smoker (range 5 to 8 cigarettes/ day)	None	-Root fracture 52,94 % -Endodontic root treatment failure 41,18 % -Advanced caries lesions 5,88%	Socket-shield technique and immediate implantation
Gluckman et al. 2018 (retrospective study)	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	128	70 F 58 M	24–71 (mean 39 years)	-	-	Patients had previously SST	SST and immediate implantation
Siormpas et al. 2018 (retrospective study)	The Root Membrane Technique: A Retrospective Clinical Study with Up to 10 Years of Follow-Up	182	82 M 100 F	range: 18-83 years	- No 139 (76.4 %) -Light (<10 cigarettes/d) 15 (8.2 %) -Strong (≥10 cigarettes/d) 28 (15.4 %)	- No 163 (89.6 %) -Yes 19 (10.4 %)	-Tooth fracture 153 (61.2 %) -Destructive caries 91 (36.4 %) Internal/ external root resorption 2 (0.8 %) -Recurrentuntreatable endodontic -infection 4 (1,6 %)	Root membrane technique and immediate implant placement
Siormpas et al. 2014	Immediate implant placement in the esthetic zone utilizing the "root-membrane" technique: clinical results up to 5 years post-loading	46	20 M 26 F	Mean age: 53 years Range, 28 to 70 years	-	NO	45 teeth: non-restorable due to extensive caries or supra-crestal horizontal fracture 1: cervical root resorptio	Root membrane and immediate implantation
Mitsias et al. 2017	The Root Membrane Technique: Human Histologic Evidence after Five Years of Function	1	M	68 years	-	NO	Non-restorable teeth due to horizontal fracture	Root membrane technique and immediate implantation
Durrani et al. 2020	Socket shield: An esthetic success?	15	11 M 4 F	22 to 55 years	NO	NO	Fractured upper anterior tooth	Socket-shield technique and immediate implant placement
Mitsias et al. 2020	Longitudinal Soft Tissue Changes during Periodontal Ligament-Mediated Immediate Implant Placement with the Root-Membrane Technique	10	4 M 6 F	-	-	NO	Single hopeless tooth	PDL-mediated implant placement

TABLE 1 Patient information and indications for socket-shield or root membrane technique in the studies analyzed.

Study	Title	Implant site	Drilling axes	Shield's height	Shield's thickness	Contact Shield-implant	Grafting the Gap	Implant Design
Baumer et al. 2017	Socket shield technique for immediate implant placement–clinical, radiographic and volumetric data after 5 years	One front tooth (from upper first premolars to premolars)	Through the root	1 mm above the buccal bone	2-3 mm	Direct Touch	NO	Parallel-walled implant (SPI Element, Thommen Medical, Waldenburg, Switzerland)
Hinze et al. 2018	Volumetric alterations around single tooth implants using the socket-shield technique: preliminary results of a prospective case series		Through the root	1 mm above the buccal bone plate	1-2 mm	Without Contact of the implant to the root fragment	NO	SPI Contact, Thommen Medical
Gluckman et al. 2018	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	Maxillary incisors (64%), premolars (22%), canines (14%); maxilla (89.9%), mandible (10.1%)	-	The authors proposed at the level of bone crest	-	-	-	Internal, morse-taper, conical connection implants only (AnyRidge, MegaGen; Ankylos, Dentsply; NobelReplace, Nobel Biocare)
Siormpas et al. 2018 (retrospective study)	The root membrane technique: a retrospective clinical study with up to 10 years of follow-up	Maxilla 230 (92%) Mandible 20 (8%)	The implant drill through the long axis of the root membrane.	1 mm above the bone crest	1,5 mm	Direct touch	NO	Cylindrical implants with self-tapping threads and a sandblasted surface (EzPlus; MegaGen, Gyeongbuk, South Korea) or tapered implants with knife-edge threads and a nanostructured calcium-incorporated surface (Anyridge; MegaGen).
Siormpas et al. 2014	Immediate implant placement in the esthetic zone utilizing the "root-membrane" technique: clinical results up to 5 years post-loading	Maxillary anterior region	The implant drill through the long axis of the root membrane.	1 mm above the bone crest	≥1 mm	Direct touch	NO	Tapered implant (EZ plus internal, MegaGen implant)
Mitsias et al. 2017	The root membrane technique: human histologic evidence after five years of function	Anterior maxilla: tooth #12	The implant drill through the long axis of the root membrane.	1 mm above bone crest	Thin layer	Direct touch	NO	-
Durrani et al. 2020	Socket shield: An esthetic success?	Upper and lower anterior dentition	Through the bone only	At the alveolar crest	2 mm	Without Contact	Bone grafts (Biooss, Geistlich Pharma)	Tag Implants (T. A. G. Medical Products Corporation Ltd., Kibbutz Gaaton, Israel)
Mitsias et al. 2020	Longitudinal soft tissue changes during periodontal ligament-mediated immediate implant placement with the root-membrane technique	Single tooth in the anterior maxilla	Through the root canal area of the tooth	1 mm above the bone crest	-	Without touch Thickness 0.5 mm to 1 between implant and retained fragment	NO	Root membrane kit, MegaGen, Tapered implant

TABLE 2 Author's perception to perform SST or root membrane technique in the included studies.

Study	Title	Follow up period	Complications	Mean loss of buccal tissue	Implant facial recession =	Facial recession at the neighboring teeth	Mean Change of the level of gingival margin	Mean loss of marginal bone level	Clinical outcome	Pink and white aesthetic score	Conclusion
Baumer et al. 2017	Socket Shield Technique for immediate implant placement–clinical, radiographic and volumetric data after 5 years	51 to 63 months (mean 58 months	NONE	0.37 ±0.18 mm	0.33 ±0.23 mm	0.38± 0.27 mm	-	0.33 ±0.43 mm at the mesial and 0.17 0.36 mm at the distal aspect of the implants	Sufficient amount of keratinized mucosal width of 3–5 mm buccal of the implants	Mean score of 12	-Promising technique - too early for routine clinical application - Need long term follow-up studies
Hinze et al. 2018	Volumetric alterations around single toothimplants using the socket-shield technique: preliminary results of a prospective case series	5 years	NONE	5-year mean recession was < 0.5 mm (-0.07 ± 0.16; range -0.37 to +0.32at 3 months follow-up	No influence was found	-	3-month follow-up, mesial papilla height =0,31 mm & distal papilla height=0,38 mm	-	3 –month follow-up, High PROM pain and function	-	SST+ immediate provisiona-lization minimize buccal contour changes.
Gluckman et al. 2018	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	4 years	-25 complications (19.5% complication rate). -5 non-osseointegra-tedimplant/ -16 SS exposure -3 infection sites. -1 SS migration/ over-erupted	-	2 mm soft tissue recession	-	-	-	Learning curve reduces complications.	-	-Sensitive technique -More studies needed -ISR similar to conventional techniques
Siormpas Et al. 2018 (retro-spective study)	The Root Membrane Technique: A Retrospective Clinical Study with Up to 10 Years of Follow-Up	(8–10 years of follow-up	5 implant failures, -implant survival: 97.3% (implant-based) and 96.5% (patient based) -complications: 8 adverse events, only 2 contributed to implant failure	-	-	-	-	-	Predictable clinical outcomes and high long term survival rate	-	Long term safe and reliable technique with few biological complications
Siormpas et al. 2014	Immediate implant placement in the esthetic zone utilizing the "root-membrane" technique: clinical results up to 5 years post-loading	Median follow-up: 40 months (range 24,to 60 months	Complication: apical root resorption of the retained fragment (1 failure), the implant was functional	-	-	-	-	0.18 ± 0.09 mm at the mesial mm and 0.21 ± 0.09 mm at the distal aspects of the implants	100% success rate for a cumulative 5 years	-	Safe technique contributing to high implant success rate -Gold standard for the immediate implant protocol in the aesthetic area.
Mitsias et al. 2017	The Root Membrane Technique: Human Histologic Evidence after Five Years of Function	5 years	No complication except that the patient had a traumatic injury	uccal bone maintained with healthy periodontal tissues	-	-	-	-	Osseointegration with high amount of compact and mature bone on its surface Bone to implant contact 76.2%	-	Effective technique in preventing buccal bone's resorption
Durrani et al. 2020	Socket shield: An esthetic success?	5 years	1 failure: as pus from the shield, with an osseo-integratedimplant	No buccal collapse	-	-	-	-	Implant survival, crestal bone levels, and the pink esthetic score were stable in all the cases.	Quite impressive	Safe surgical approach, predictable and impressive results without the use of unpredictable regenerative surgeries and expensive biomaterials
Mitsias et al. 2020	Longitudinal Soft Tissue Changes during Periodontal Ligament-Mediated Immediate Implant Placement with the Root-Membrane Technique	Median : 55 months	NO	Excellent Tissue stability Neared 0, <0.5 mm	Excellent tissue stability neared 0; <0,5 mm	-	-	-	PDL-mediated immediate implant was not inferior to no extraction, 0 tissues change	-	-Optimal soft tissues stability in the aesthetic zone. -Need for more controlled clinical studies to assess the benefits of its use compared to the others.

TABLE 3 complications, radiographic results and clinical outcomes of SST or root membrane technique.

protocol, especially in the anterior area. The clinical outcomes are predictable and impressive avoiding the placement of unreliable regenerative surgeries and expensive biomaterials.
- Comparing SST with conventional techniques, the implant survival rate is analogous. Moreover, SST demonstrated less biological complications, thus, it is safe but sensitive and needs careful instructions to execute it. More controlled clinical trials are needed to determine the advantages of its use in comparison to alternative options.

A group of Japanese researchers (22) showed in their recent systematic review in 2021 an assumption about the effectiveness of the SST. They recommended including this procedure in dental implant therapy, although high-quality data needs to be available besides the lack of evidence of its long-term effectiveness. They claimed that future investigations with higher scientific evidence, such as randomized clinical trials are necessary to develop this concept's biological credibility and clinical success.

Furthermore, Bäumer and Hürzeler reviewed radiographically the SST first cases outcomes at five years, and reported a bone resorption of 0.33±0.43 mm and 0.17±0.36 mm, respectively, mesially and distally beside the implant (15). Bramanti et al. published in 2018 a study with the goal of determining the SST's survival and success rate, as well as comparing the acquired outcomes with those achieved from the same immediate implant procedure. The findings showed that the SST outperformed the other group (conventional protocol of extraction- implant placement) in terms of peri-implant bone resorption, as identified by the table below (1). In addition, to evaluate the soft tissue aesthetics of the SST with the conventional one, Baümer and Hürzeler; used the Pink esthetic score (PES) analysis in their five-year study that noted a mean score of 12 (15). Similarly, in the study done by Bramanti et al., the SST had a higher score than the conventional one; thus, SST seems to provide a more cosmetic outcome (1).

As shown in table 2, there are slight differences in the step-by-step protocol of the SST. In fact, Siormpas, Mitsias, Baumer and Hinze applied the drilling axis through the long axis of the root, before even removing the palatal fragment (15-18, 20, 21). According to these authors, the shields height in the corono-apico direction must be 1 mm above the buccal bone. However, Gluckman, Hürzeler and Durrani did the drilling axis through the bone only and considered the shield's height must be at the level of buccal bone (1, 9, 11). Performing the drilling axis through the bone while using a surgical template helps to ensure the palatal direction of the implant in the socket. Nonetheless, the authors supporting the implant bed preparation through the root explained that this procedure could secure the implant bur, which is surrounded with dentin. In the table 2, there are minor variations in the heights of the shield, thus, after referring to a various studies concerning the shield's height in the corono-apico region, Hürzeler et al determined in his latest article that reducing the shield to the level of the buccal bone may contribute to a resorption of 1 mm of buccal bone. In spite of this resorption, the final outcome continue to preserve a highly aesthetic and success rate (11). This assumption of Hürzeler resulted when one of the complications of this technique appears to be an external exposure of the shield, hence shortening the shield to 1 mm above the buccal bone seems to be not the optimal choice. Other factors examined in our study in table 2 are the shield's thickness, which varies from a thin layer to 3 mm. To emphasize, there is no standard step-by-step protocol concerning the ideal thickness, position of the shield in socket, height in the apico-corono direction, drilling axis and even whether to create contact or not with the shield. The direction touch with the retained fragment appeared to be important when the clinicians apply "the locking principle". This previous concept was introduced in 2020 by Hürzeler as a solution to the migration of the shield (11). As per Gluckman et al. this problem happened once at that time in 2017, and it did not affect the restoration (10). However, Zuhr et al. faced this complication in a study 6 years after the surgery (23). In fact, as elaborated above about the continuous growth of the upper jaw in an antero-caudal orientation, the shield as well as natural teeth can move coronally (11). Two solutions were proposed by the clinicians to avoid the shield's mobility: the first is to create a tooth to implant contact among the implant and the shield, the second is to extend the root fragment sufficiently in the apico-coronal orientation to enable bone formation between the implant and the fragment (11). Therefore, the ankylosis that follows prevents the root fragment from shifting in the path of skeletal progression (10,23). Another section studied in table 2 in our review is "grafting the socket". This section is still debatable. Notwithstanding, latest publication by Hürzeler et al. showed that there is no need for grafting materials to cover the gap (11). Multiple studies have noticed the body's ability to heal, demonstrating bone formation and ankylosis of both the implant and shield. In brief, those materials appear to be needless and can obstruct the healing procedure (8, 11, 24). This is in sharp contrast to the findings of Durrani and Bramanti et al, who established that a bone graft in conjunction with the SST is essential (19, 1, 25).

In short, SST is a reliable approach when combined with immediate implant insertion. Nevertheless, it is a delicate procedure that requires careful instructions to master. There are also limitations in our understanding that necessitate well-designed, monitored clinical trials with more significant sample sizes.

The SST literature stated a lack of evidence concerning the impact of implant positioning and design on the success rate. As a future perspective, the clinicians can benefit from the use of a suitable implant shape that promotes the success of the SST, such as progressively

tapered implants or cylindrical implants with aggressive macro design in the apical part, thus achieving high primary stability. In addition, a narrow diameter implant in the coronal part may promote thick tissue formation and secure long-term aesthetic and functional results.

CONCLUSION

After tooth extraction, alveolar ridge collapse is a severe problem, compromising the cosmetic result in the anterior zone. The bundle bone is a tooth-relying architecture; thus, tooth extraction causes irreversible buccal bone resorption, eventually contributing to vertical, horizontal papilla collapses and even gingival recession. Existing socket preservation techniques are restricted to avoiding ridge collapse after tooth removal. Partial extraction therapies, such as "socket-shield," "pontic shield," and "root submergence," are an effective way to avoid alveolar bone loss by retaining the tooth itself or a portion of it. SST is meticulous alternatives with a big future in preventing alveolar bone from resorption after tooth removal, preserving the bundle bone resorption, and providing a long-term esthetic outcome. The SST has been studied widely in the literature, and several studies suggest that immediate implant positioning with the SST offers the best cosmetic and functional performance. The most significant disadvantage of SST appears to be the delicate surgical method.

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