Current Evidence on the Socket-Shield Technique: A Systematic Review

Amit S. Gharpure, BDS[1]*
Neel B. Bhatavadekar, BDS, MS, MPH[2]

The recently popularized socket-shield technique involves intentional retention of a section of the remnant root at the time of immediate implant placement, thereby preserving the buccal/proximal bone from resorption. The objective of this systematic review was to assess the literature available on the socket-shield technique and weigh its biological plausibility and long-term clinical prognosis. A systematic search was performed on PubMed-Medline, Embase, Web of Knowledge, Google Scholar, and Cochrane Central for clinical/animal studies from January 1970 to April 2017. Twenty-three studies were assessed: 1 clinical case-control study, 4 animal histological reports, 1 clinical abstract, and 17+2* case reports. Eighteen out of the 23 studies had a duration of $\leq$12 months. A quality assessment of 5 studies (4 animal histologic and 1 clinical case-control) performed using the modified Animal Research: Reporting of In Vivo Experiments guidelines revealed that 4/5 studies had low scores. Fifty-eight out of 70 (82.86%) implants from 4 animal histological studies had complications; buccal/crestal bone loss (54.55%) and failure of osseointegration (27.27%) were the most common. Thirty-three out of 136 (24.26%) implants from 19+2 (2 studies had both histologic and clinical components, which are assessed separately) clinical studies had complications; buccal/crestal bone loss (78.78%) and shield exposure/failure (12.12%) were the most common. Other complications recorded were periodontal ligament and cementum formation on implant surfaces, pocket formation, inflammation, mucositis, and peri-implantitis. However, some clinical reports indicated stable results at 12 months. It would be difficult to predict the long-term success of this technique until high-quality evidence becomes available.

A video abstract is available for viewing at https://youtu.be/lNMeUxj2XPA?list=PLvRxNhB9EJqbqjcYMbwKbwi8Xpbb0YuHI.

Key Words: dental implant, dental cementum, periodontal ligament, socket-shield, systematic review, complications, adverse effects

INTRODUCTION

Tooth extractions are followed by multiple dimensional changes in the remnant alveolar bone.[1–5] It has been postulated that retention of the root may alter the physiologic changes seen in extraction sockets.[6] Multiple studies have demonstrated that retaining decoronated roots, either vital or endontically treated (such as the root submergence technique[7]) can preserve the alveolar bone at an extraction site.[8–11] There have also been a few publications that have studied the effect of implants being placed in contact with or in close approximation to retained root pieces, which demonstrate the formation of periodontal ligament and/or cementum on implant surfaces.[12–15]

More recently, there has been an interest in placing implants in close proximity to or in contact with intentionally retained roots to preserve the buccal bone.[6,16–20] Hurzeler et al were the first researchers to describe the socket-shield technique, which they claimed would help preserve the buccal bone after extraction. A buccal root fragment was intentionally retained at the time of extraction, as depicted in Figure 1. The root fragment functioned like a shield that preserved the buccal bone from resorption; thereafter, an immediate implant was placed palatal to the root fragment. The histologic study by Hurzeler et al[6] was an animal model that demonstrated the formation of cementum on implant surfaces placed in contact with intentionally retained roots. Using the same principle, other researchers further modified the original technique to preserve the proximal bone[17,19] and the crestal bone.[21,22] Another animal histologic study—a circumferential root fragment design—demonstrated the formation of a fibrous capsule around implants.[23] At present, all clinical human studies currently available using the technique of implants placed in close proximity to intentionally retained root fragments are lower in the hierarchy of evidence, as seen in Figure 2. Our aim was to systematically analyze the available literature on this technique, understand its viability, and draw conclusions on its clinical outcome. The primary objective of this systematic review was to answer two fundamental questions: (1) has the socket-shield technique demonstrated a good long-term prognosis in terms of clinical success and (2) does this technique, which is used to improve the outcome of implant therapy—especially in the anterior esthetic zone—have sufficient biologic plausibility?

To the best of the authors' knowledge, this was the first systematic review on the socket shield-technique.

[1] Periodontics, University of Washington School of Dentistry, Seattle, Wa.
[2] Clarus Dental Specialities, Pune, India; University of North Carolina at Chapel Hill, NC.
* *Corresponding author,* e-mail: amitsg188@gmail.com
DOI: 10.1563/aaid-joi-D-17-00118

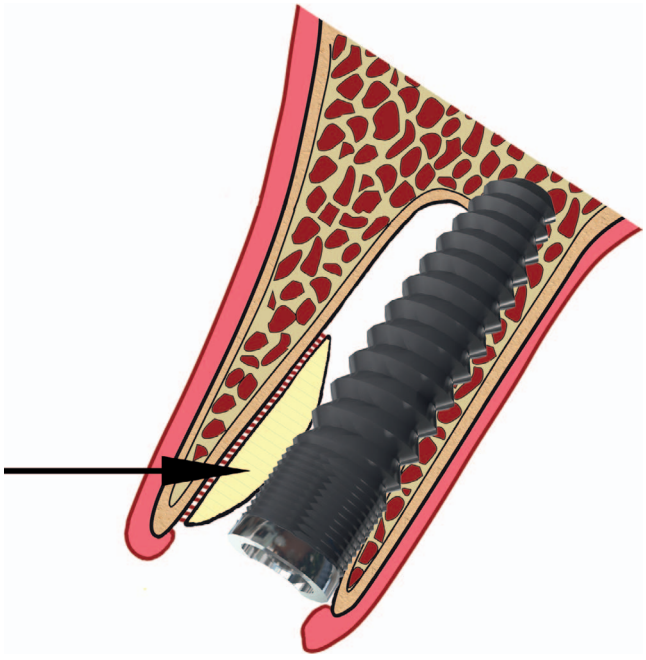


Figure 1. Diagrammatic representation of the socket-shield technique: The black arrow indicates the root fragment retained to serve as a "socket-shield" to prevent resorption of buccal bone. Placement of implant is palatal/lingual to this root fragment.

Figure 2. Schematic representation of the search protocol used for the selection of studies used in the systematic review.

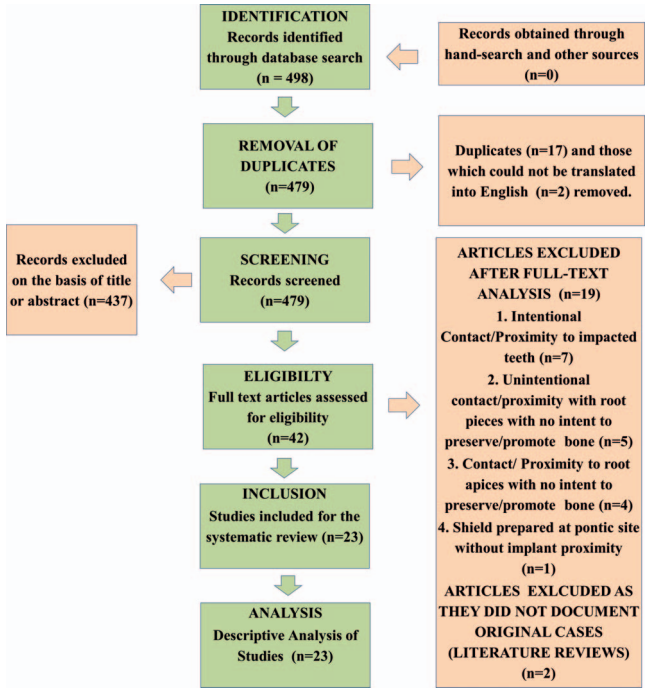


Figure 3. Distribution of available literature according to the hierarchy of evidence.

Materials and Methods

This systematic review was performed in line with the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[24] We also followed the guidelines provided by the Cochrane Handbook for Systematic Reviews.[25] The focused population, intervention, control, outcome (PICO) question of the present systematic review was, "What is the long-term clinical prognosis and the biologic plausibility of the socket-shield technique used for preservation of buccal/proximal/crestal bone for implant treatment in humans on the basis of clinical, histologic, and radiologic evaluation?" The secondary objectives of the study were to provide a qualitative assessment of the available literature and a statistical distribution of the adverse effects and complications associated with this technique. Initially, it was decided to include all randomized control trials. However, due to unavailability of clinical trials, cohort studies, and systematic reviews, we decided to include clinical reports as well, although they were lower on the hierarchy of evidence.

Information sources and search protocol

A systematic search was performed in PubMed-Medline, Embase, Web of Knowledge, Google Scholar, and the Cochrane Central Register of Controlled Trials from January 1970 to April 2017. Figure 3 depicts the search protocol followed. The systematic search, without language restriction, used the search terms "socket-shield," "root membrane," "implant proximity to teeth," "implant placement in contact with root," "periodontal ligament formation on implant surface," "cementum," "periodontal ligament," "dental implants," and "immediate implants" in various combinations with Boolean operators "AND" and "OR" with no restrictions set on the document type. The reference lists of published trials, review articles, meta-analyses, and case reports/series were also examined to identify other eligible studies. Additionally, high quality peer-review dentistry journals were hand searched. There were no restrictions placed on the duration of the study and the followup.

Inclusion and exclusion criteria

Studies were included if they met the following criteria: (1) root canal treatment (RCT), cohort, case-control, case series/report, or clinical abstract and (2) based on the socket-shield principle,

in which implants are placed in close proximity or in contact with root fragments that are intentionally retained to preserve or promote buccal/proximal/crestal bone. Exclusion criteria were studies (1) in which root-fragments were not left back intentionally to preserve or promote buccal/proximal/crestal bone and (2) in which implants were unknowingly placed in proximity or in contact with retained roots.

Screening and selection of papers

Both authors assessed the studies, and any conflicts in study selection were resolved through discussion. Studies were assessed on the basis of their titles or abstracts, and those studies meeting the inclusion criteria were selected for full text review. The selected papers were then assessed for eligibility (Figure 3).

Assessment of complications and adverse effects

Complications and adverse effects were defined as histologic, clinical, or radiologic detrimental effects that would diminish the long-term success of the implant treatment. For animal studies, clinical outcomes assessed were implant/shield exposure, presence of inflammation, mucositis, or peri-implantitis. Histologic outcomes assessed were failure of osseointegration or formation of periodontal ligament (PDL) or cementum on the implant surface. Radiologic outcomes assessed were buccal/crestal bone loss. For clinical studies, clinical outcomes assessed were shield (root fragment) exposure, probing pocket depths, or deficiency of alveolar ridge. Radiologic outcome assessed was buccal/crestal bone loss. The studies that met the criteria were analyzed for complications and adverse effects as reported by their respective authors. Data tables, histologic images, radiographs, and clinical images presented in these studies were also analyzed to identify overlooked/missed complications.

Data collection process

Predefined data collection spreadsheets were employed for assessment of each publication (Table 1) and consisted of authors' names, year of publication, time of implant placement, loading protocol, complications and adverse effects, and duration. Evaluations were carried out independently by both authors and confirmed after comparison. When in doubt concerning the extracted data, corresponding authors were contacted by e-mail for confirmation.

Quality assessment in individual studies

A quality assessment was performed for the animal studies and the human case-control study using a modification of the Animal Research: Reporting of In Vivo Experiments (ARRIVE) guidelines specifically designed to assess the quality of experimental research in implant dentistry.[26,27] Each study was given a score based on various points of the ARRIVE guidelines, with a maximum score of 28.

Data synthesis for meta-analysis

Heterogeneity of the data was assessed to determine if a meta-analysis could be performed. The level of agreement between the reviewers regarding relevant factors in the studies was determined using kappa statistics. Data was analyzed using SPSS software (SPSS Statistics for Windows, Ver. 23.0. IBM Corp, Armonk, NY).

Results

A total of 498 articles were found with the initial search strategy after using combinations of various key words. Duplicate articles were removed, and titles and abstracts of all articles were screened. Articles in languages other than English—such as Dutch, German, and Standard Mandarin—were translated; those unavailable in English ($n = 2$) were discarded. Four hundred thirty-seven articles were rejected on the basis of their titles and abstracts. After screening, 42 articles were selected for further analysis. Full texts of the articles were assessed for eligibility: 19 articles were excluded, 7 recorded implants placed in impacted teeth, 5 described implant proximity to undetected retained root apices, and 4 documented implants placed in contact with intentionally retained root apices without any intention of bone promotion/preservation. The 3 studies by Gluckman et al[28–30] were excluded: 2 were literature reviews that focused on specific techniques without complete documentation of original cases,[29,30] and 1 involved pontic shields without clear mention of total number of implants exclusively placed with socket-shield technique.[28]

Study characteristics and outcomes

A total of 23 studies were included in this systematic review. The distribution of the available literature according to its hierarchy is shown in Figure 2. One was a case-control study, 4 had animal histologic reports, with 2 of them[6,16] accompanied by a human case report. One study was an abstract documenting 23 original cases.[31] The remaining 17 articles were clinical human case reports and case series. Details of the studies are provided in Table 1. The frequencies and percentages of the complications and adverse effects were calculated and listed in Tables 2 and 3 and in Figures 4 and 5.

Quality assessment in individual studies

A quality assessment based on modified ARRIVE guidelines specifically designed for experimental research in implant dentistry[26,27] was performed on 4 animal studies and 1 case-control study; their scores out of a total of 28 are shown in Table 4. The remaining studies were case reports or case series that were ineligible for a quality assessment.

Data synthesis for meta-analysis

A meta-analysis could not be performed due absence of homogeneity among the studies and the lack of well-designed randomized controlled trials. However, we performed a percentage-wise statistical distribution of complications and adverse effects (Tables 2 and 3). Kappa statistics showed a high level of agreement between the reviewers ($\kappa > 0.80$).

TABLE 1

Details of the all the histologic and animal studies on the socket-shield technique along with a description of their complications and adverse effects*

Serial No.	Study Authors and Reference No.	Sample Size	Time of Implant Placement
Histologic Studies			
1.	Parlar et al[23]	9 mongrel dogs, 18 implants	Immediate
2.	Hurzeler et al[6]†	1 beagle dog, 4 implants	Immediate
3.	Baumer et al[16]‡	3 beagle dogs, 12 implants	Immediate
4.	Guirado et al[21]	6 American Foxhound dogs, 36 implants	Immediate
Clinical Studies			
—	Hurzeler et al[6]†	1 patient, 1 implant	Immediate
—	Baumer et al[16]‡	1 patient, 1 implant	Immediate
5.	Abadzhiev et al[32] (case-control study)	25 patients, 26 implants (10 implants with shields)	Immediate
6.	Kan and Rungcharassaeng[17]	1 patient, 1 implant	Immediate
7.	Chen and Pan[33]	1 patient, 1 implant	Immediate
8.	Cherel and Etienne[19]	1 patient, 2 implants	Immediate
9.	Siormpas et al[18]	46 patients, 46 implants	Immediate
10.	Glocker et al[20]	3 patients, 3 implants	Delayed, 6 months
11.	Troiano et al[22]	7 patients, 10 implants	Immediate
12.	Gluckman et al[34]	1 patient, 1 implant	Immediate
13.	Al Dary and Al Hadadi[35]	1 patient, 1 implant	Immediate
14.	Wadhwani et al[36]	1 patient, 1 implant	Immediate
15.	Lagas et al[49]	16 patients, 16 implants	Immediate
16.	Mitsias et al[38]	1 patient, 1 implant	Immediate
17.	Holbrook[37]	1 patient, 1 implant	Immediate
18.	Chen and Chen[42]	4 patients, 4 implants	Immediate
19.	Abitbol et al[31]	20 patients, 23 implants	Immediate
20.	Al Dary[39]	1 patient, 1 implant	Immediate
21.	Hong Huang et al[40]	1 patient, 1 implant	Immediate
22.	Saeidi Pour et al[41]	1 patient, 1 implant	Immediate
23.	Baumer et al[43]	10 patients, 10 implants	Immediate

*PDL indicates periodontal ligament.

†‡These studies had a histological and clinical component and are repeated in both sections.

§Not included in statistical analysis due to an absence of consensus in the literature on acceptable values.

DISCUSSION

Parlar et al were the first to place 18 implants positioned in the center of prepared hollow chambers of decoronated roots with slits at the periphery in nine mongrel dogs (Table 1).[23] Four months later, histological examination of the specimens showed newly formed periodontal ligament, alveolar bone, and root cementum in the space between the implant and the wall of the dentin chamber. A fibrous capsule covered their surfaces, and they failed to osseointegrate with cellular cementum deposition on 2 implants and 1implant exposure.[23] Hurzeler et al[6] intentionally left a buccal portion of the remnant root coated with enamel matrix derivative (EMD; Emdogain, Straumann Group, Basel, Switzerland) to preserve the buccal

TABLE 2

A quantitative description of the total sample size, number of studies, and total complications and adverse effects associated with the implants and root pieces in the socket-shield technique

Type and Number of Studies	Total Cases	Total Complications and Adverse Effects
Histological studies (n = 4)	19 dogs, 70 socket-shields with 70 implants	58 (82.86%) implants
Clinical studies (n = 19+2*)	144 patients, 136 socket-shields with 136 implants†	33 (24.26%) implants

*Two studies had clinical and histologic components and are included in both groups.

†Did not include cases where the total implant number was not specified.

Table 1

Extended

Implant Loading Protocol	Complications and Adverse Effects	Duration of the Study
N/A	Fibrous tissue around all implants, failure to osseointegrate 2 implant surfaces—cementum formation 1 implant exposure 2 sites inflammation	4 months
N/A	2 implants surfaces—cementum formation 2 implant surfaces—PDL formation	4 months
N/A	None	4 months
N/A	3 implants – mucositis and peri-implantitis. Mean crestal bone loss ranging from 3.13 ± 0.54 mm to 6.01 ± 2.23 mm Small fractures in some cases showed resorptive process	4 months
Immediate	None	6 months
Delayed, 6 months	Mean buccal bone loss of 0.88 mm, range 1.67 mm to 0.15 mm.	6 months
Not specified	Mean crestal bone loss of 0.8 mm	24 months
Immediate	None	12 months
Delayed, 4 months	Mean buccal bone loss of 0.72mm	12 months
Immediate	Coronal part of root fragment visible through mucosal bed after removal of temporary crowns	11 months
Immediate	Mean crestal bone loss of 0.18 ± 0.09 mm on mesial and 0.21 ± 0.09 mm on palatal§ 1 case of apical root resorption of socket shield	24–60 months (median 40)
Not specified	None	6 months
Delayed, 3 months	Mean crestal bone loss 1.3 ± 0.2 mm	6 months
Immediate	None	12 months
Immediate	None	5 months
Delayed, 4 months	None	4 months
10/16 Immediate	1 shield failed due to infection 1 case showed deficiency of alveolar ridge	0.50–2.85 years
Immediate	Up to 4 mm probing pocket around implant at 3 months†	36 months
Immediate	None	12 months
Not specified	Mean buccal bone loss of 0.83 ± 0.178 mm	3 months
Immediate	probing pocket of 8 mm in the mesio-buccal part of one shield, 1 shield exposure	12 months
Delayed	None	3 months
Delayed, 6 months	None	12 months
Immediate	None	3 months
Immediate 4/10, Delayed 6/10	None	51–63 months (mean 58)

cortical plate from resorption during an immediate implant placement (Figure 1) and were the first to name this technique "socket-shield." Histological examination of 4 implants placed in a beagle dog demonstrated cementum formation on implant surface where direct root-implant contact was noted. When the implant and the root piece were in close proximity with no surface contact, a 0.5 mm connective tissue band was found between the implant and the buccal root piece. They also presented a clinical case report using this technique wherein the implant was immediately loaded and followed up for 6 months (Table 1). Baumer et al[16] further investigated this technique by employing a similar study design but with a larger sample size (Table 1). Their histologic evaluation showed osseointegration and bone formation between the fragments and the implants after 4 months of healing. They also presented a clinical case report (Table 1). The histologic study by Guirado et al[21] compared the effects of varying thickness of the socket-shield and the buccal alveolar bone on the success of this technique. Irrespective of the thickness of the socket-shield and bone used, there was a rapid crestal bone loss noted at 4 months, ranging from 3.13 ± 0.54 mm to 6.01 ± 2.23 mm.

The duration of all four histologic studies was only 4 months. As seen in Table 3 and Figure 4, the implants demonstrated complications such as crestal bone loss (54.55%),[21] failure to osseointegrate (27.27%),[23] formation of PDL (3.03%),[6] and cementum (6.06%)[6,16] on their surfaces. Another important factor to be considered is the quality of the animal studies. Scores of the modified ARRIVE quality assessment scale for 3 out of 4 studies,[6,16,23] were 15, 15, and 16 out of a total score of 28, respectively (Table 4) or well below the average of 19.35 ± 3.78 out of 28 reported in implant studies carried out in dogs.[27] These low scores may further undermine the findings of the studies. Thus, the current histologic evidence is insufficient to support the biologic plausibility of this technique.

The only case-control study on the socket-shield was published by Abadzhiev et al[32] with details described in Table 1. Though the socket-shield group had better results in terms of bone loss, esthetics, and soft tissue volume, a mean bone loss

TABLE 3

Frequency and percentage distribution of the complications and adverse effects of the socket-shield technique*

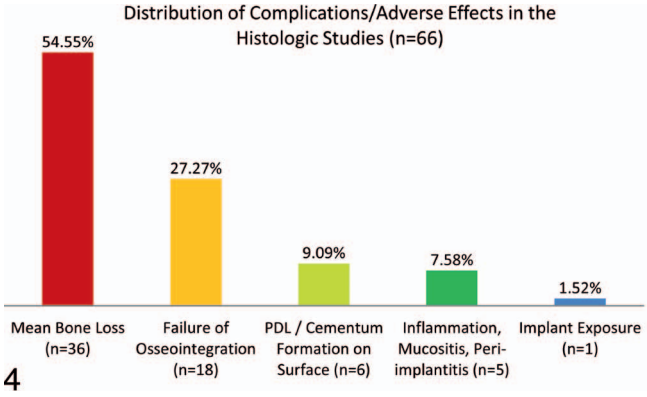
Nature of Complications/Adverse Effects	No. of Reported Cases
Histologic studies	
1. Mean crestal bone loss from 3.13 ± 0.54 mm to 6.01 ± 2.23 mm at 4 months[21]	36 (54.55%)
2. Failure of osseointegration due to fibrous healing[23]	18 (27.27%)
3. Inflammation, mucositis and peri-implantitis[21,23]	5 (7.58%)
4. Cementum-like hard tissue formation[6,23]	4 (6.06%)
5. PDL-like tissue formation on implant surface[6]	2 (3.03%)
6. Implant exposure[23]	1 (1.52%)
Total no of complications	66 (100%)
Total documented implants with complications/undesired outcomes in histologic studies	58
Clinical studies	
1. Mean bone loss around implants (total cases)	26 (78.78%)
Crestal loss of 1.3 ± 0.2 mm at 6 months[22]	10
Buccal loss of 0.88 mm at 6 months[16]	1
Buccal loss of 0.83 ± 0.178 mm at 3 months[42]	4
Crestal loss of 0.8mm at 24 months[32]	10
Buccal loss of 0.72 mm at 12 months[33]	1
2. Shield exposure/failure (total cases)	5 (15.15%)
Shield failure due to infection[49]	1
Coronal part of shield exposed on mucosal bed at 3–4 months[19]	2
Shield exposure at 12 months[31]	1
Apical root resorption[18]	1
3. Probing depths (total cases)	1 (3.03%)
8 mm at 12 months[31]	1
4. Deficiency of alveolar ridge[49]	1 (3.03%)
Total documented implants with complications/undesired outcomes in clinical studies	33 (100%)

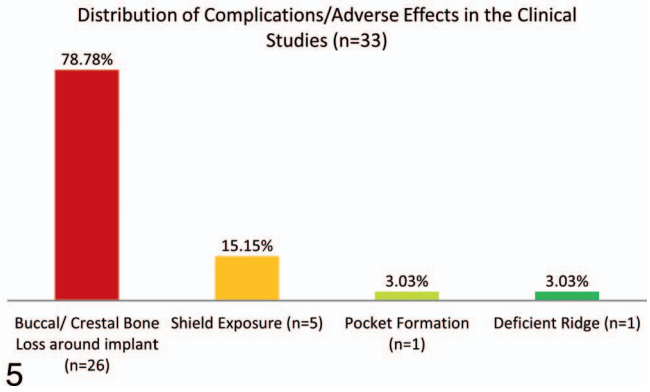
*PDL indicates periodontal ligament.

of 0.8 mm (2%) was noted at 24 months.[32] However, the group scored 4 out of a total of 28 (Table 4) on the modified ARRIVE quality assessment scale,[25,26] which is extremely low as compared to mean score of 19.2 ± 2.58 out of 28 seen in other clinical implant studies.[27] Such a low score may undermine the results of this study and reduce the generalizability and external validity of its findings. Description of the various case series and reports based on the socket-shield technique and their complications are seen in Table 1. A majority of case reports documented this technique for single implant restorations in the anterior esthetic region[33–38] and involved immediate implant placement at the time of preparation of the socket-shields. Some clinicians made modifications to the original technique in terms of time of implant placement[20] and location of the shield[17,22] but followed the same principle.

Thirteen case reports and abstracts published the findings of only 1 patient each (Table 1).[6,16,17,19,33–41] Thus, the possibility of case selection bias cannot be ruled out, wherein the authors might have presented only those cases with successful outcomes. Sixteen clinical human studies show short-term followup of ≤12 months (Table 1).* Such short periods are insufficient to effectively demonstrate the failures and complications of this technique. Thus, there is a high

*References 6,16,17,19,20,22,31,33–37,39–42.





FIGURES 4 AND 5. FIGURE 4. Graphical representation of the distribution of complications/ adverse effects in the histologic studies on the socket-shield technique included in this review. **FIGURE 5.** Graphical representation of the distribution of the complications/adverse effects in the clinical studies on the socket-shield technique included in this review.

TABLE 4

A quality analysis of the animal studies and human case-control study according to the modified ARRIVE guidelines for assessing quality in implant research (Vignoletti and Abrahamsson[27]). Scores were assessed for each point and a total score was calculated.

Number	Score Range	Item Name	Parlar et al[23]	Hurzeler et al[6]	Baumer et al[16]	Guirado et al[21]	Abadzhiev et al[32]
1	0–2	Title	1	1	1	1	1
2	0–2	Abstract	1	1	1	1	0
3	0–2	Introduction and Background	1	1	1	1	0
4	0–1	Objectives	1	1	1	1	0
5	0–1	Methods Ethics Statement	0	1	1	1	0
6 a	0–1	Study Design	1	1	1	1	1
6 b	0–1		0	0	0	1	0
7 a	0–1	Experimental Procedures	1	1	1	1	0
7 b	0–1		1	1	1	1	N/A
7 c	0–1		1	1	1	1	0
8	0–1	Experimental Animals/ Subjects	1	1	1	1	1
9	0–1	Housing and Husbandry /Dental History	0	0	0	1	0
10 a	0–1	Sample Size	1	1	1	1	1
10 b	0–1		0	0	0	0	0
11	0–1	Experimental Outcomes	1	1	1	1	0
12 a	0–1	Statistical Methods	N/A	N/A	N/A	1	0
12 b	0–1		N/A	N/A	N/A	1	0
12 c	0–1		N/A	N/A	N/A	0	0
13	0–1	Results, Numbers analysed	1	1	1	1	0
14	0–1	Outcomes and Estimation	N/A	N/A	N/A	1	0
15	0–1	Adverse Effects	1	0	0	0	0
16	0–2	Discussion/Interpretation	1	1	1	1	0
17	0–1	Generalizability/Translation	0	0	1	0	0
18	0–1	Funding	1	1	1	1	0
	0–28	Total Score	15	15	16	20	4

possibility that the number of complications, adverse effects, and failures is under-reported. What also needs consideration is that publications by certain groups of authors[18,43] showed very good long-term results, whereas few other publications[21–23] had a high number of complications and adverse effects. This probably indicates that the socket-shield procedure might be technique sensitive.

Multiple studies in the past have documented the fate of root pieces left after undetected root fractures at the time of extraction.[44–46] One clinical human study documented that 16.2% of fractured root pieces in a sample size of 2000 became symptomatic.[45] In another study, histologic evaluation of fractured root pieces left during extraction revealed that 27% of them had pathologies such as sinus tracks, inflammation, and cysts.[46] Further, the root pieces showed signs of continuous resorption and repair with acellular cementum formation.[46] More recently, complications of infection and bone loss were demonstrated when implants were placed in contact with unnoticed retained root pieces at the time of extraction.[47,48] The clinical studies in this review presented with several types of complications and adverse effects, such as crestal/buccal bone loss (78.78% of all reported complications), exposure of the shield, and deep probing pockets (Table 3, Figure 5). Thus, there is a possibility that the socket-shield may pose a risk of infection to those implants placed in close proximity. Further, there is a possibility that loss of the socket-shield either by resorption or extraction following infection may lead to loss of the bone it preserves, predisposing the implant surface to exposure.

This systematic review has its share of limitations. Although a variety of search terms were used for this technique and sincere efforts were made to review all relevant literature, certain articles might have been missed if describing the same technique but using a different name. Also, certain studies that could not be translated into English were not included in the study. All clinical studies discussed (except Abadzhiev et al[32]) are case reports, each with their own sets of methodologies and parameters for assessment, making comparisons of outcomes difficult. As a result, only 5 studies could be included for the modified ARRIVE quality analysis (Table 4). Moreover, there is a possibility of underestimating the actual complications due to possible operator bias in the individual reports that could not be assessed. It must be noted that this paper has provided only a descriptive assessment of the cases and is limited in interpretation of the results, determination of prognosis, and extrapolation of the findings.

CONCLUSION

After going through available literature, overall evidence in support of the socket-shield technique seems limited at the present. Histologic evidence indicates rapid bone loss, failure of osseointegration, formation of cementum, and PDL or PDL-like fibrous tissue on implant surfaces in proximity to the shield, weakening the biologic plausibility of this technique. Case reports with short followups are insufficient for a long-term clinical prognosis of this socket-shield technique. Future studies that are higher on the hierarchy of evidence—such as RCTs and well-designed prospective cohorts—are required to fully

establish the biologic plausibility and clinical success of this technique.

Abbreviations

ARRIVE: Animal Research: Reporting of In Vivo Experiments
EMD: enamel matrix derivative
PDL: periodontal ligament
RCT: root canal treatment

Notes

There was no support in the form of funding for this study. The authors declare that there was no conflict of interest.

References

1. Amler MH, Johnson PL, Salman I. Histological and histochemical investigation of human alveolar socket healing in undisturbed extraction wounds. *J Am Dent Assoc*. 1960;61:32–44.

2. Araujo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. *J Clin Periodontol*. 2005;32: 212–218.

3. 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;35:906–913.

4. Pietrokovski J, Massler M. Alveolar ridge resorption following tooth extraction. *J Prosthet Dent*. 1967;17:21–27.

5. 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;23:313–323.

6. 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;37:855–862.

7. 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;27:521–527.

8. Filippi A, Pohl Y, von Arx T. Decoronation of an ankylosed tooth for preservation of alveolar bone prior to implant placement. *Dent Traumatol*. 2001;17:93–95.

9. Andersson L, Emami-Kristiansen Z, Hogstrom J. Single-tooth implant treatment in the anterior region of the maxilla for treatment of tooth loss after trauma: a retrospective clinical and interview study. *Dent Traumatol*. 2003;19:126–131.

10. Sapir S, Shapira J. Decoronation for the management of an ankylosed young permanent tooth. *Dent Traumatol*. 2008;24:131–135.

11. Malmgren B. Decoronation: how, why, and when? *J Calif Dent Assoc*. 2000;28:846–854.

12. Buser D, Warrer K, Karring T. Formation of a periodontal ligament around titanium implants. *J Periodontol*. 1990;61:597–601.

13. Warrer K, Karring T, Gotfredsen K. Periodontal ligament formation around different types of dental titanium implants. I. The self-tapping screw type implant system. *J Periodontol*. 1993;64:29–34.

14. Gray JL, Vernino AR. The interface between retained roots and dental implants: a histologic study in baboons. *J Periodontol*. 2004;75:1102–1106.

15. Jahangiri L, Hessamfar R, Ricci JL. Partial generation of periodontal ligament on endosseous dental implants in dogs. *Clin Oral Implants Res*. 2005;16:396–401.

16. 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;17:71–82.

17. Kan JY, Rungcharassaeng K. Proximal socket shield for interimplant papilla preservation in the esthetic zone. *Int J Periodontics Restorative Dent*. 2013;33:e24–e31.

18. 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;29:1397–1405.

19. Cherel F, Etienne D. Papilla preservation between two implants: a modified socket-shield technique to maintain the scalloped anatomy? A case report. *Quintessence Int*. 2014;45:23–30.

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

21. Guirado JL, Troiano M, Lopez-Lopez PJ, 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.

22. Troiano M, Benincasa M, Sánchez P, Calvo-Guirado J. Bundle bone preservation with Root-T-Belt: case study. *Ann Oral Maxillofac Surg*. 2014;2:7.

23. Parlar A, Bosshardt DD, Unsal B, Cetiner D, Haytac C, Lang NP. New formation of periodontal tissues around titanium implants in a novel dentin chamber model. *Clin Oral Implants Res*. 2005;16:259–267.

24. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *The BMJ*. 2009;339:b2535.

25. Higgins JPT, Green S, eds. Cochrane handbook for systematic reviews of interventions Version 5.1.0 [updated March 2011]. The Cochrane Collaboration, 2011. http://handbook-5-1.cochrane.org/. Accessed September 26, 2017.

26. Kilkenny C, Browne W, Cuthill IC, Emerson M, Altman DG. Animal research: reporting in vivo experiments: the ARRIVE guidelines. *J Gene Med*. 2010;12:561–563.

27. Vignoletti F, Abrahamsson I. Quality of reporting of experimental research in implant dentistry. Critical aspects in design, outcome assessment and model validation. *J Clin Periodontol*. 2012;39(suppl 12):6–27.

28. Gluckman H, Du Toit J, Salama M. The pontic-shield: partial extraction therapy for ridge preservation and pontic site development. *Int J Periodontics Restorative Dent*. 2016;36:417–423.

29. Gluckman H, Salama M, Du Toit J. Partial extraction therapies (PET) Part 1: maintaining alveolar ridge contour at pontic and immediate implant sites. *Int J Periodontics Restorative Dent*. 2016;36:681–687.

30. Gluckman H, Salama M, Du Toit J. Partial extraction therapies (PET) Part 2: procedures and technical aspects. *Int J Periodontics Restorative Dent*. 2017;37:377–385.

31. Implant insertion after tooth extraction: clinical outcomes with different approaches (including socket preservation, immediate, early and delayed placement). *Clin Oral Implants Res*. 2016;27:530.

32. 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;1:176–180.

33. Chen C, Pan Y. Socket shield technique for ridge preservation: a case report. *J Prosthodont Implantol*. 2013;2:16–21.

34. Gluckman H, Du Toit J, Salama M. The socket-shield technique to support the buccofacial tissues at immediate implant placement. *Int Dent Afr Ed*. 2015;5:6–14.

35. Al Dary H, Al Hadidi A. The socket shield technique using bone trephine: a case report. *Int J Dent Oral Sci*. 2015;5:1–5.

36. Wadhwani P, Goyal S, Tiwari S, Syed S, Paul T, Komal A. Socket shield technique: a new concept of ridge preservation. *Asian J Oral Health Allied Sci*. 2015;5:55–58.

37. Holbrook SE. Model-guided flapless immediate implant placement and provisionalization in the esthetic zone utilizing a nanostructured titanium implant: a case report. *J Oral Implantol*. 2016;42:98–103.

38. 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;35:835–841.

39. Al Dary H. Socket shield technique with and without implant placement to maintain pink aesthetics: case report. *Smile Dent J*. 2016;11:16–20.

40. Huang H, Shu L, Liu Y, Wang L, Li J, Fu G. Immediate implants combined with modified socket-shield technique: a case letter. *J Oral Implantol*. 2017;43:139–143.

41. Saeidi Pour R, Zuhr O, Hürzeler M, et al. Clinical benefits of the immediate implant socket shield technique. *J Esthet Restor Dent*. 2017;29:93–101.

42. Chen W-C, Chen C-I. A preliminary clinical study of buccal bone

alteration using the socket-shield technique and immediate implant placement. *J Taiwan Acad Periodontol*. 2016;21:137–145.

43. Bäumer D, Zuhr O, Rebele S, Hürzeler M. Socket shield technique for immediate implant placement – clinical, radiographic and volumetric data after 5 years. *Clin Oral Implants Res*. In press.

44. Nayyar J, Clarke M, O'Sullivan M, Stassen LF. Fractured root tips during dental extractions and retained root fragments. A clinical dilemma? *Br Dent J*. 2015;218:285–290.

45. Helsham RW. Some observations on the subject of roots of teeth retained in the jaws as a result of incomplete exodontia. *Aust Dent J*. 1960;5: 70–77.

46. Herd JR. The retained tooth root. *Aust Dent J*. 1973;18:125–131.

47. Guarnieri R, Giardino L, Crespi R, Romagnoli R. Cementum formation around a titanium implant: a case report. *Int J Oral Maxillofac Implants*. 2002;17:729–732.

48. 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;35:305–313.

49. Lagas LJ, Pepplinkhuizen JJFAA, Bergé SJ, Meijer GJ. Implant placement in the aesthetic zone: the socket-shield-technique. *Ned Tijdschr Tandheelkd*. 2015;122:33–36.