Socket shield technique: An unconventional method for immediate implant placement - A review

ABSTRACT
The aim of this review is to present the currently available studies on the treatment outcome of socket shield technique (SST) with an attempt to compare it with the conventional technique for immediate implant placement. An electronic search was performed using PubMed, Google Scholar, and Cochrane databases. All relevant human studies reporting the treatment outcome of SST in conjunct with immediate implant placement were included. In vitro studies, case reports, reviews, systematic reviews and articles not related to SST were excluded. The initial electronic database search identified 606 articles. After removing the duplicates, reading the titles and abstracts, 19 articles were eligible for full-text reading. Two case series were excluded as the specific treatment outcomes of the clinical cases were not mentioned. Further, one article was included after hand searching of the reference lists. Eighteen articles were included for the final review. These 18 articles consisted of 15 full texts and 3 abstracts. Out of them, 3 were randomized controlled trials, 7 were retrospective studies, 4 were prospective studies, 1 was a prospective case series, 1 was a prospective nonrandomized controlled study and 2 were comparative studies. This review concludes that though the implant survival rate may be comparable in SST and the conventional technique, the SST seems to perform better in terms of bone preservation, esthetic outcome, and patient satisfaction. Furthermore, further randomized clinical trials are required to generate strong evidence for recommending SST over the conventional technique for long-lasting successful treatment outcomes with immediate implants.

Keywords: Immediate implant, review, socket shield technique, treatment outcome

INTRODUCTION
There has been a recent drift in treatment goals which focuses now on implant treatment success instead of merely on implant survival.¹,² Although the conventional immediate implant placement has a good implant survival rate, it comes across some adverse esthetic outcomes in anterior regions ensuing from labial plate resorption, gingival recession, and recession of the papillae.³⁻⁴ The socket-shield technique (SST) has emerged as a promising treatment modality to preserve the buccal cortical bone for immediate implant placement in esthetic areas.

The concept of socket-shield technique
It is well established that the tooth extraction is followed by alveolar ridge resorption owing to the loss of the periodontal ligament (PDL) and its blood vessels that primarily vascularize the bundle bone of the tooth.⁷ Thus, it was assumed that root retention might have an influence on the occurring resorption process. Consequently, Hürzeler et al.⁸ proposed the concept of SST in 2010 by conducting an experiment in a beagle dog with the goal to histologically assess and clinically demonstrate the effect of buccal root retention in combination with immediate implant placement. In this unconventional method of immediate implant placement, the buccal root fragment is retained during the extraction,

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Received: 13 April 2020, Revised: 08 June 2020, Accepted: 04 August 2020, Published: 05 May 2022

How to cite this article: Sharma A, Maheshwari K, Tiwari B, Naik D. Socket shield technique: An unconventional method for immediate implant placement - A review. Natl J Maxillofac Surg 2022;13:S24-35.
followed by implant placement. It acts as a natural shield which limits the buccal bone resorption and improves the contour of the tissues, which helps in achieving predictable esthetic outcomes.

Clinical steps involved in socket-shield technique

1. Three-dimensional imaging of the preparation site and the tooth using cone-beam computed tomography (CBCT) is required for meticulous planning of immediate implant placement using SST.\(^9\)
2. Following adequate anesthesia of the planned site, the tooth is decoronated to the gingival level with care taken not to damage the adjacent structures (gingiva, adjacent teeth, or restorations)
3. Thereafter, tooth root is carefully sectioned mesio-distally midway through the root till the apex with a long shank surgical root resection bur under copious irrigation in such a way that the labial and palatal halves are separated from each other. Absolute care is to be taken not to penetrate bone or neighboring teeth mesially or distally.
4. A microperiotome instrument is inserted into the palatal PDL space, carefully displacing the palatal root section labially into the recess created by the sectioning bur and retrieving it with microforceps.
5. Thereafter, the coronal aspect of the buccal root section is reduced and shaped to within 1 mm above the alveolar crest by a large round diamond bur under copious irrigation.
6. The root section is then reduced to approximately half its thickness from root canal to its labial limit and shaped as a crescent-shaped concavity conforming to the labial aspect of the alveolus.
7. The socket is thoroughly rinsed, and the root section inspected with a sharp probe for immobility.
8. The final completed labial tooth section acts as the socket shield and is ready for subsequent implant placement at its palatal aspect.

Clinical application of socket-shield technique

SST is indicated in both the jaws where immediate implants have to be placed to replace nonrestorable teeth with deep caries but healthy PDL or in ankylosed teeth.\(^7,\,8\) It aims at the preservation of labial/buccal bone at the time of immediate implant placement, thereby maintaining the hard- and soft-tissue contours. Even the interdental papilla can be preserved in cases where adjacent implants are to be placed.\(^10\) It may be used in cases of vertical root fractures not involving the buccal aspect and horizontal tooth fractures above bone level. It also maintains the pink esthetics and hence can be effectively used in esthetically critical cases such as high lip line and in maxillary anterior regions.\(^11\) The retained root fragment (socket shield) also acts as a guide for the correct positioning of the implant. As this technique minimizes the need of the soft- and hard-tissue grafting procedures, it decreases the overall treatment duration and cost. The number of clinical appointments can also be reduced by using SST associated with a computer-aided designed/computer-aided manufactured fabricated surgical guide.\(^12\)

Limitations of the socket shield technique

The case selection for the implementation of SST is very critical. Although the technique may be intended for application at all tooth sites, it is at the clinician’s discretion to use it at posterior sites with smaller, curved, or divergent roots. Being technique sensitive,\(^13\) it requires a high degree of clinical skill and expertise. Active periodontitis at the tooth is an absolute contraindication for preparing it as socket shield.\(^9\) Mobile teeth, malaligned teeth, and teeth with large periapical lesions should be avoided. Extreme care needs to be taken to prevent any mobility in the shield. Another possible late complication can be extrusion of the retained root with the associated risk of caries, inflammation, or pocket formation. This, in turn, may lead to discoloration or recession of the soft tissues or exposed implant parts becoming visible.\(^11\)

AIM OF THE REVIEW

The SST is an unconventional and a relatively new method for immediate implant placement. Therefore, the aim of this review is to present the currently available studies on the treatment outcome of SST with an attempt to compare it with the conventional technique for immediate implant placement.

METHODOLOGY

Review question

Does the SST with immediate implant placement help in the preservation of bone and improvement in esthetics? Is this technique better than the conventional technique for immediate implant placement?

Population, Intervention, Comparison, Outcomes analysis

- Population - Patients requiring immediate implant placement
- Intervention - Immediate implant placement with SST
- Comparison - Immediate implant placement with SST compared with conventional immediate implant placement technique
- Outcome - Treatment outcome of SST with immediate implant placement, which includes implant survival, implant stability, any associated complications and implant success in terms of hard and soft-tissue changes, esthetics, patient satisfaction.
Literature search
An electronic search was performed using PubMed, Google Scholar, and Cochrane databases from January 1, 2010 to January 31, 2020. The search terms included were “SST,” “root membrane technique,” “socket preservation,” “ extraction socket,” “partial extraction therapy,” “root retention,” and “dental implant.” No restrictions for the study design and language were applied in the literature search.

Article eligibility criteria
The inclusion and exclusion criteria were already defined by the authors. For inclusion, the publications had to be human studies; however, there was no language restriction in the selection of relevant articles. The relevant non-English articles were translated into English with the help of Google Translate and were included in the review. The study design included were randomized clinical trials, comparative studies, retrospective/prospective studies, case series, and abstracts from the conference proceedings. Publications had to assess the treatment outcome of SST in conjunct with immediate implant placement. Studies comparing the SST and the conventional technique were also included. In vitro studies, case reports, reviews, systematic reviews, and articles not related to SST were excluded.

Articles screening and selection
A screening process was undertaken independently by two reviewers (AS and KM). Each reviewer screened the articles after reading the titles to exclude the irrelevant articles. Studies not reporting on SST, animal studies, in vitro studies, case reports, and review articles were excluded after reading the abstracts. The full texts of relevant articles were assessed according to the eligibility criteria. The cross-references of the publications were also checked. Any disagreements between the two reviewers were resolved after additional discussion with a third reviewer (BT).

Data extraction from the included studies
Data were extracted from the included studies for the final review and spread in a customized table with 13 columns under the headings- Author and year of publication, study design, mean age and number of patients, number of implants, implant site, grafting, follow-up period, study objectives, implant survival, complications, clinical outcome, esthetic outcome, and study conclusion.

RESULTS
Screening of articles for their eligibility
The flowchart for the screening of articles according to the inclusion and exclusion criteria is presented in Figure 1. Initial electronic database search identified 606 articles. After removing the duplicates and reading the titles, 122 potentially relevant articles were identified. After reading their abstracts, 19 articles were eligible for full-text reading. These included 3 Chinese language articles and 1 Dutch language article, which were translated into English. Two case series were excluded as the specific treatment outcomes of the clinical cases were not mentioned. Further, one article was included after hand searching of the reference lists. Eighteen articles were included for the final review. These 18 articles consisted of 15 full texts and 3 abstracts. Of the three abstracts, full text of 1 article could not be obtained, and the other 2 articles were the abstracts from the conference proceedings, which documented the clinical outcomes of SST. Detailed analysis of the included studies is presented in Table 1.

Characteristics and outcomes of included studies
Detailed analysis showed that of the included studies, 3 were randomized controlled trials, 7 were retrospective studies, 11 were prospective studies, and 2 were comparative studies. A quantitative analysis of the total number of patients, the total number of implants placed with SST and complications associated with the SST is presented in Table 2. In these 18 clinical studies, 656 patients were treated and a total of 664 implants were placed with SST. 10 implants failed and were removed. Thirty-two complications occurred, which did not lead to implant removal. The descriptive analysis of complications is presented in Figure 2.

DISCUSSION
Implant survival, failure, and complications
In the studies included in the present review, 656 patients were treated and a total of 664 implants were placed with SST. Out of these 664 implants, the survival of 10 implants in the study by Abadzhiev et al.[14] and 8 implants in the study by Tiwari et al.[29] has not been reported. Hence, these 18 implants have not been taken into consideration for implant survival rate. Of the remaining 646 implants, 636 implants had survived and 10 implants had failed. This amounts to a very high implant survival rate of 98.45% with SST. Among the 10 implants which failed and were removed; 7 implants failed to osseointegrate and 3 implants were removed due to untreatable peri-implantitis. There were 32 complications in 646 implants placed with SST, but these complications were managed and did not lead to implant removal. The major reported complications/adverse effects in SST were internal and external shield exposures, shield infection, shield migration, loosening of the abutment, pocket formation, and apical root resorption.
Of all the complications in this review, a total of 20 socket shield exposures have been reported by Gluckman et al.\textsuperscript{[19]} Kher et al.\textsuperscript{[25]} and Abitbol et al.\textsuperscript{[17]} Gluckman et al.\textsuperscript{[19]} reported 12 cases of internal exposure and 4 cases of external exposure. Rounding off the top edge of the root fragment and flushing it with alveolar crest reduce the chance of root membrane exposure.\textsuperscript{[26]} The internal exposure of socket shield (towards restoration) is due to the lack of adequate space between the coronal edge of the shield and the subgingival contour of the crown. An overextended or sharp-edged coronal portion of

Table 1: Data extraction from the included studies

| Author and year of publication | Study design | Mean age and number of patients | Number of implants | Implant site | Grafting | Follow-up period |
|-------------------------------|--------------|---------------------------------|-------------------|-------------|----------|-----------------|
| Abadzhiev et al. (2014)\textsuperscript{[46]} | Comparative study | 20-64 years, 25 patients | 26 (10 with SST and 16 with conventional technique) | Frontal aesthetic region | Xeno bone graft mixed with platelet rich in growth factors extracted from the patients' blood | 2 years |
| Sirompas et al. (2014)\textsuperscript{[26]} | Retrospective study | 28-70 years, 46 patients | 46 (SST) | Maxillary incisors and canines | No grafting | 24-60 months |
| Lagas et al. (2015)\textsuperscript{[39]} | Retrospective study | 22-77 years, 16 patients | 16 (SST) | Maxillary anterior | Not mentioned | 1.28 years |
| Abitbol et al. (2016)\textsuperscript{[71]} | Retrospective study | 55.6 years, 20 patients | 23 (SST) | Not mentioned | Xenograft or allograft | 1 year |
| Barakat et al. (2017)\textsuperscript{[26]} | Randomized controlled trial | 20-50 years, 20 patients | 20 (10 with SST and 10 with conventional technique) | Maxillary incisors and canines | Not mentioned | 7 months |
| Bäumer et al. (2017)\textsuperscript{[71]} | Retrospective study | ≥25 years, 10 patients | 10 (SST) | Maxillary region between first premolars | Enamel matrix protein | 51-63 months |
| Gluckman et al. (2017)\textsuperscript{[39]} | Retrospective study | 24-71 years, 128 patients | 128 (SST) | Maxillary and mandibular incisors, canines and premolars | Not mentioned | 4 years |
| Hinze et al. (2018)\textsuperscript{[26]} | Prospective case series | 26.44-65.98 years, 15 patients | 17 (SST) | Maxillary and mandibular incisors and premolars | Not mentioned | 5 years |
| Bramanti et al. (2018)\textsuperscript{[27]} | Randomized controlled trial | Not mentioned, 40 patients | 40 (20 with SST and 20 with conventional technique) | Anterior region between maxillary/mandibular canines | Allograft in control group | 3 years |
| Sirompas et al. (2018)\textsuperscript{[22]} | Retrospective study | 18-83 years, 182 patients | 250 (SST); 230 in maxilla and 20 in mandible | Anterior maxilla and/ or mandible- central and lateral incisors, cuspids, first premolar | No grafting | 10 years |
| Han et al. (2018)\textsuperscript{[22]} | Prospective study | 20-82 years, 30 patients | 40 (SST); 34 in maxilla and 6 in mandible | Anterior region-incisors, cuspids, and premolar of maxilla and mandible | No grafting | 1 year |
| Zhu et al. (2018)\textsuperscript{[26]} | Prospective study | Not mentioned, 9 patients | 10 (SST) | Maxillary anterior region | Not mentioned | 1-4 years |
| Kher et al. (2018)\textsuperscript{[29]} | Retrospective study | 54.78 years, 17 patients | 21 (SST) | Esthetic zone | No grafting | 12-42 months |
| Yan et al. (2019)\textsuperscript{[26]} | Prospective study | 18-48 years, 10 patients | 10 (SST) | Maxillary central incisors | Bio-Oss bone powder | 1 year |
| Xu et al. (2019)\textsuperscript{[22]} | Prospective nonrandomized controlled study | 25-52 years (SST) and 27-53 years (control group), 24 patients | 24 (12 with SST and 12 with conventional technique) | Maxillary central and lateral incisors | Bio-Oss bone powder | 1 year |
| Walid and Alkhodary (2019)\textsuperscript{[24]} | Prospective study | 25-45 years, 18 patients | 18 (SST) | Maxillary central or lateral incisor | Bioactive glass (calciumphosphosilicate) | 1 year |
| Tiwari et al. (2019)\textsuperscript{[24]} | Comparative study | 18-30 years, 16 patients | 16 (8 with SST and 8 with conventional technique) | Maxillary anterior teeth | No grafting | 1 year |
| Sun et al. (2020)\textsuperscript{[26]} | Randomized clinical study | >25 years, 30 patients | 30 (15 with SST and 15 with conventional technique) | Anterior region (incisors, canine) | Deproteinized bovine bone mineral | 2 years |

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Table 1: Contd...

| Author and year of publication | Study objectives | Implant survival rate | Complications | Clinical outcome | Esthetic outcome | Study conclusion |
|--------------------------------|------------------|-----------------------|---------------|------------------|-----------------|------------------|
| Abadzhiev et al. (2014)[14]   | To compare SST with conventional technique for immediate implant placement in terms of bone loss, soft tissue volume and aesthetics | Not mentioned | Not mentioned | Up to 5 mm bone loss in conventional technique contrary to 0.8 mm in SST | A predominant natural appearance of socket-shield treated teeth | The SST is much more promising strategy for immediate implant placement for preserving buccal bone volume and better aesthetics |
| Siormpas et al. (2014)[11]    | To clinically evaluate and report longitudinal data on implant survival rate for immediate implant placement with simultaneous intentional retention of the buccal aspect of the root | 100% | No subjective adverse events except one case of apical root resorption of a single retained root fragment that did not interfere with the osseointegration of the implant | The mean crestal bone loss on the mesial and distal aspect of the implants was estimated to be $0.18 \pm 0.09$ and $0.21 \pm 0.09$ mm, respectively | The clinical characteristics of the peri-implant mucosa was indiscernible from those of the gingiva surrounding the proximal teeth | The intentional retention of the buccal aspect of the root with its periodontal apparatus during immediate implant placement can lead to predictable and sustainable osseointegration of implants placed in the maxillary anterior region |
| Lagas et al. (2015)[14]       | To evaluate the esthetic outcome of SST | 100% | One socket shield had to be removed because of infection | Not reported | PES = 12.31 | SST provides a high esthetic outcome in maxillary anterior area |
| Abitbol et al. (2016)[11]     | To evaluate clinical results with the SST; implant stability, bone level and esthetic outcomes | 100% | A probing pocket of 8 mm in the mesio-buccal part of the root and an exposition of the root in another case | No signs of bone loss at the alveolar crest | Improved pink aesthetic score | Retaining the buccal aspect of the root during implant placement does not appear to interfere with osseointegration and may be beneficial in preserving the buccal bone plate |
| Barakat et al. (2017)[12]     | To evaluate the SST clinically and radiographically in comparison to the conventional technique | 100% | None | The mean horizontal and vertical bone loss value in SST was $0.09 \pm 0.03$ mm and $0.43 \pm 0.23$ mm respectively contrary to $0.32 \pm 0.14$ mm and $1.56 \pm 0.77$ mm in the conventional implantation Mean change in probing depth = $0.33 \pm 0.12$ (SST) and $0.63 \pm 0.32$ (conventional technique) Sulcus bleeding index had score of zero in all the patients | Not reported | SST appears to be a safe technique to achieve osseointegration and preserve alveolar bone without any inflammatory response |
| Bäumer et al. (2017)[11]      | To gain insight into biological and implant-related long-term complications, to observe the clinical appearance of the peri-implant tissues and to evaluate volumetric changes of the affected facial contours in long-term and the esthetic outcome | 100% | None | MBL = $0.33 \pm 0.43$ mm at mesial and $0.17 \pm 0.36$ mm at distal aspect A sufficient amount of keratinized mucosal width of 3-5 mm buccal of the implants | PES = 12 | SST offers reduced invasiveness at the time of surgery and high esthetic outcomes with effective preservation of facial tissue contours |
| Gluckman et al. (2017)[10]    | To report on implant survival using SST | 96.1% | Five implants failed to osseointegrate and were removed. Twelve incidences of internal exposure and 4 cases of external exposure. One socket shield migrated and 3 developed infection | Signs of peri-implantitis, clinically or radiographically, was not noted in any of the cases followed-up | Blue-gray hue as a sign of implant reslucency through the gingival tissue was not noted in any cases | The SST technique performs comparably to conventional delayed and immediate implant placement in terms of implant survival and complication rate |

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| Author and year of publication | Study objectives                                                                                                                                                                                                                                                                                                                                 | Implant survival rate | Complications | Clinical outcome                                                                                                                                                                                                                                                                                                                                 | Esthetic outcome | Study conclusion                                                                                                                                                                                                                                                                                                                                 |
|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sharma et al. (2018)          | To demonstrate prospectively that immediate implant placement and provisionalization combined with SST will result in long lasting volume stability of peri-implant mucosa                                                                                                                                   | 100%                | None          | Soft tissue contour change in buccal direction was <0.5 mm (−0.37−+0.32). Mean change of gingival margin level was 0.17 ± 0.67 mm. Mesial and distal papilla height changed at a respective mean of 0.31 ± 0.64 mm and 0.38 ± 0.57 mm                                                   | Clinical appearance of the gingiva was harmonious, attractive and showed no signs of inflammation | Preservation of buccal root fragment in conjunction with immediate implant placement and provisionalization is a viable technique to minimize buccal contour changes after tooth extraction |
| Bramanti et al. (2018)        | To evaluate the survival and success rate of dental implants inserted with SST                                                                                                                                                                                                                                                                  | 100%                | None          | MBL = 0.605±0.06 (SST), 1.115±0.131 (control group)                                                                                                                                  | PES = 12.15±0.76 (SST); 10.3±2.53 (control group) | The SST seems to be a safe surgical technique that allows an implant rehabilitation characterized by better aesthetic outcomes                                                                                           |
| Siormpas et al. (2018)        | To document the long-term clinical and radiographic results of the root membrane technique                                                                                                                                                                                                                                                  | 96.5%               | Five implant failed (2 implants removed due to failure in osseointegration and 3 implants removed due to untreatable peri-implantitis). 2 cases developed root fragment infection with fistula and 1 case developed root fragment infection with perimplant mucositis | Massive bone loss in the implants that failed due to infection                                                                                                                       | Not reported   | The intentional retention of the buccal aspect of the root with its periodontal apparatus during immediate implant placement leads to predictable clinical outcomes and satisfactory high survival and success rates in the long-term |
| Han et al. (2018)             | To investigate the survival, stability, and complication rates of implants placed using a “modified” SST                                                                                                                                                                                                                                  | 100%                | Loosening of one abutment 2 months after insertion; no biological complications                                                                                                       | ISQ at placement = 72.9±5.9 and ISQ after 1 year = 74.6±2.7                                                                                                                       | Not reported   | The root fragment does not interfere with osseointegration and may be beneficial for the esthetics, protecting the buccal bone from resorption                                                                                                                                                     |
| Zhu et al. (2018)             | To evaluate the preliminary clinical outcome of SST in maxillary anterior region                                                                                                                                                                                                                                                              | 100%                | None          | Mesial and distal bone loss were 0.17 and 0.22 mm, respectively                                                                                                                      | PES = 13.5      | Immediate implant placement with SST achieves good esthetic results in maxillary anterior region                                                                                                                                                                                                 |
| Kher et al. (2018)            | To evaluate the clinical and radiographic outcomes of SST without the use of bone grafts                                                                                                                                                                                                                                                   | 100%                | Shield exposure at 3 implant sites Midfacial recession at one site                                                                                                                    | Stable marginal bone levels were recorded                                                                                                                                           | PES = 1.2       | The SST yielded successful outcome without the use of bone grafts                                                                                                                                                                                                                       |
| Yan et al. (2019)             | To observe the clinical effect of immediate implant placement with root membrane technique                                                                                                                                                                                                                                                | 100%                | None          | Decrease in the thickness of the hard tissue at neck, middle, and root of the implants = (0.27±0.21), (0.19±0.20), and (0.28±0.23) respectively                                                                 | Pink aesthetic index was 9.10±0.54, and the white aesthetic index was 9.00±0.63 | The RMT in maxillary anterior teeth area cannot completely avoid the resorption of hard tissue on the labial side of the implant, but it can effectively reduce the resorption of the labial bone plate and the aesthetic effect is good |

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the shield leads to the development of external exposure of the socket shield (toward oral cavity). The external exposures occur more frequently at sites which are inherently deficient in facial bone (lower anterior, cuspids, previous orthodontic treatment). The exposures can be managed by the reduction of the exposed portion with a diamond bur attached to a

| Author and year of publication | Study objectives | Implant survival rate | Complications | Clinical outcome | Esthetic outcome | Study conclusion |
|-------------------------------|------------------|-----------------------|---------------|------------------|-----------------|-----------------|
| Xu et al. (2019) [27]          | To compare the clinical effects of improved SST and traditional immediate implantation in the aesthetic area | 100% | None | Labial bone thickness after 1 year=2.90±0.64 (SST) and 2.51±0.69 (control group) | PES=13.25±0.75 (SST) and 11.83±0.94 (control group) | SST is beneficial to maintain the labial bone mass, so as to obtain a better soft tissue aesthetic effect |
| Walid and Alkhodary (2019) [28] | To test the effect of SST on maintaining the labial plate of bone and surrounding gingival tissues on immediate placement of different dental implants systems | 100% | None | No vertical resorption of labial bone plate and no gingival recession was recorded | Improved and maintained pink esthetics with interdental papillae filled their spaces in most of the cases | The socket SST was able to maintain the labial plate of bone and the position of the overlying free gingival margin, with the neighboring interdental papillae showing least dimensional changes |
| Tiwari et al. (2019) [29]     | To compare the efficacy of immediate implant placement after extraction without SST and with SST in the esthetic region | Not reported | Not reported | Labial bone loss at crest at 12th month follow-up=0.03±0.025 mm (SST) versus 0.168±0.013 mm (conventional technique) | Not reported | The SST demonstrated better preservation of bone, thus eliminating the need for any bony substitutes |
| Sun et al. (2020) [30]       | To assess the esthetic and clinical outcomes of immediate implantation using the conventional flap-less approach and the SST | 100% | None | SST versus control group ISQ=76.01±1.31 versus 75.56±1.07 BPW=1.15±0.27 mm and BPH=2.59±0.21 mm versus BPW=0.83±0.13 mm and BPH=1.82±0.18 mm PD=1.23±0.02 versus 2.00±0.09 mSBI=0.78±0.03 versus 1.13±0.13 mPLI=1.19±0.04 versus 1.74±0.04 | PES=12.07±1.62 in SST group versus 11.33±1.76 in control group | SST seems to be a promising treatment approach for implants in the esthetic zone. |

SST: Socket shield technique, ISQ: Implant stability quotient, PES: Pink esthetic score, BPW: Bone plate width, BPH: Bone plate height, PD: Probing depth, mSBI: Modified sulcus bleeding index, mPLI: Modified plaque index, RMT: Root membrane technique, MBL=Marginal bone loss
According to Han in their study reported no significant changes one buccal root fragment had to 1.5 mm, 664 10 reported 1–2 mm, 656 reported the bone loss at the neck, middle, and 22,23,25,26 1–2 mm, 20 and 2–3 mm. 11 According to Han et al., 23 the buccal root fragment should be at least 1.5 mm to ensure resistance to fracture and resorption. The enamel matrix protein has also been used to induce the formation of new cementum on the inside of the root fragment and prevent resorption of the shield. 11

The socket also requires complete removal of the infection. 9,31,32 In a study by Lagas et al., 16 one buccal root fragment had to be removed because of infection. The infection was attributed to the incomplete removal of the old restorative material after splitting the root. Therefore, the retained buccal root portion, which acts as a shield should be prepared in such a way that the root canal contents (restorative material, gutta-percha, sealers, or neurovascular tissue) with the apex should be removed to minimize the chances of complications. This ensures the removal of microbiological leftovers in the root apex and prevents chances of apical resorption of the shield. One case of apical root resorption has been reported by Siormpas et al. 15 In this case, the resorption pit was filled with new trabecularized bone, and therefore, the implant survival was not compromised. However, the authors recommended that clinicians should employ periapical radiographs or three-dimensional evaluation for the diagnosis and monitoring of such adverse events.

The retained root fragment should be sufficiently thick to allow for the placement of implants as well as to retain its strength. The shields have been tried with various thickness such as at least 1 mm. 15,27 1.5 mm, 22,23,25,26 1–2 mm, 20 and 2–3 mm. 11 According to Han et al., 23 the buccal root fragment should be at least 1.5 mm to ensure resistance to fracture and resorption. The enamel matrix protein has also been used to induce the formation of new cementum on the inside of the root fragment and prevent resorption of the shield. 11

Table 2: Quantitative analysis of total number of patients, implants, and complications

| Number of clinical studies | Total number of patients treated with implants | Number of implants placed with SST | Number of implants failed | Number of complications |
|---------------------------|----------------------------------------------|----------------------------------|--------------------------|------------------------|
| 18                        | 656                                          | 664                              | 10                       | 32                     |

SST: Socket-shield technique

Figure 2: Graphical representation of percentage distribution of complications in the implants placed with socket-shield technique

Hard and soft tissue alterations with socket-shield technique

Bäumer et al. 11 reported 100% implant survival rate with SST with a mean loss of marginal bone level amounting to 0.33 ± 0.43 mm at mesial and 0.17 ± 0.36 mm at the distal aspect of the implants. Abadzhiev et al. 14 reported up to 12% (up to 5 mm) of bone loss in the conventional immediate implant placement contrary to only 0.8 mm in SST. Consequently, the soft-tissue volume, which was assessed by the quantity of attached gingiva, was also low in the conventional technique. Siormpas et al. 15 in their study reported good crestal bone stability with mean crestal bone loss on the mesial and distal aspects of the implants estimated to be 0.18 ± 0.09 mm and 0.21 ± 0.09 mm, respectively. All the implants successfully maintained osseointegration.

In the retrospective study by Abitbol et al., 17 no signs of bone loss were present at the alveolar crest at 1 year of follow-up. Barakat et al. 18 in a randomized controlled trial compared conventional immediate implant placement and SST and reported that the mean horizontal and vertical bone loss value in SST was 0.09 ± 0.03 mm and 0.43 ± 0.23 mm contrary to 0.33 ± 0.14 mm and 1.56 ± 0.77 mm in the conventional implantation. In the randomized controlled trial by Bramanti et al., 21 the average marginal bone resorption at 3 years of follow-up was low (0.605 ± 0.06 mm) with SST as compared to conventional technique (1.115 ± 0.131 mm). In a prospective study by Zhu et al., 24 the mesial and distal bone loss of 0.17 mm and 0.22 mm was observed respectively in 10 SST cases after an average follow-up period of 32 months. Stable marginal bone levels were recorded in all the 21 implants placed with SST in the study by Kher et al., 25 Yan et al. 26 reported the bone loss at the neck, middle, and root of the implants as 0.27 ± 0.21 mm, 0.19 ± 0.20 mm, and 0.28 ± 0.29 mm, respectively, in 10 cases of SST. Walid and Alkhodary 28 reported no significant changes in the thicknesses of the labial bone plate and absence of vertical resorption with SST during 1 year of follow-up. In a prospective nonrandomized controlled study by Xu et al., 27 the labial bone thickness after 1 year was found to be 2.90 ± 0.64 mm in the SST group and 2.51 ± 0.69 mm with the conventional technique. Similar results were reported by Sun et al. 30 in a randomized controlled trial who reported higher buccal plate width (1.15 ± 0.27 mm) and buccal plate height (2.59 ± 0.21 mm) values in SST group as compared to the control group (buccal plate width = 0.83 ± 0.13 mm and bone plate height = 1.82 ± 0.18 mm) after 6 months of...
implant placement. The results of these studies indicate that although the SST cannot completely avoid labial bone plate resorption, it can effectively reduce it. This decreased bone loss in the SST can be explained by the decreased structural destruction of the extraction sockets and maintenance of the vascular supply from the preserved PDL of the socket shield.

Bäumer et al.\textsuperscript{[11]} reported a sufficient amount of keratinized mucosal width of 3–5 mm at the buccal aspect of implants in all the ten patients. Hinze et al.\textsuperscript{[20]} assessed the soft tissue volume changes with the mean distance change of <0.5 mm in all the cases. In 5 out of 17 implants, the buccal soft-tissue volume even increased minimally in the horizontal direction. There were also positive results with the mean change in the gingival margin level and mesial and distal papilla height. This was attributed to the immediate connection of screw-retained provisional restoration supporting the marginal soft tissues with an optimized emergence profile.

**Socket shield technique and esthetics**

The studies included in the present review have reported the SST cases predominantly in the anterior esthetic region. The buccal bone plate of maxillary anterior dentition is usually very thin, which causes significant dimensional alterations during the immediate postextraction period.\textsuperscript{[33,34]} These alterations lead to apical migration of the soft tissue at the crest of the ridge as well as concavities on the labial surface of the ridge.\textsuperscript{[35]} It becomes a challenge for the clinician to place an implant and to recreate a mucosal zenith at the same level as that of gingival zenith points of the proximal teeth in such a compromised, highly esthetic site.\textsuperscript{[36]} According to Vermolen et al.,\textsuperscript{[27]} the patient pays attention not only to the “white aesthetics” of the prosthetic restoration but also on the “pink aesthetics” such as the color and shape of the marginal gingiva. Pink esthetic score (PES), proposed by Fürhauser et al.,\textsuperscript{[38]} evaluates the anterior esthetics of implant-supported single crown by focusing on soft-tissue aspects of implant restorations. The evaluation is done on seven points: mesial and distal papilla, soft-tissue height, marginal contour, alveolar process contour, soft-tissue color, and soft-tissue texture. Bäumer et al.\textsuperscript{[11]} and Kher et al.\textsuperscript{[25]} reported a PES of 12, whereas Lagas et al.\textsuperscript{[16]} and Zhu et al.\textsuperscript{[24]} reported a PES of 12.31 and 13.5, respectively, with SST. Improved PES scores were also reported by Abibol et al.\textsuperscript{[17]}, Bramanti et al.\textsuperscript{[21]} reported PES of 12.15 ± 0.76 in the SST group as compared to 10.3 ± 2.53 in the control group. Xu et al.\textsuperscript{[27]} found SST to be superior to conventional technique in pink esthetics with PES of 13.25 ± 0.75 in the SST group versus 11.83 ± 0.94 in the control group. Sun et al.\textsuperscript{[30]} also reported a better esthetic outcome in the SST group (PES 12.07 ± 1.62) than the conventional technique (11.33 ± 1.76). The clinical appearance of the peri-implant mucosa in the socket shield treated teeth was reported to be improved in other studies as well.\textsuperscript{[14,15,19,20,28]} Yan et al.\textsuperscript{[28]} used the pink and white aesthetic index proposed by Belser et al.\textsuperscript{[39]} and reported the scores as 9.10 ± 0.54 and 9.00 ± 0.63, respectively, with SST. It is mandatory to preserve and maintain the bone anatomy and overlying soft tissue architecture for a successful esthetic outcome for implant-supported restoration.\textsuperscript{[40-42]} Therefore, SST achieves better esthetic outcome because it reduces the alveolar bone resorption. In the majority of the included studies,\textsuperscript{[7,11,15,17,19,20,22,27,28,30]} the fragment had been reduced around 1 mm coronal to the labial bone plate to retain the dentogingival fibers which seemed to increase soft tissue esthetics by maintaining the mucosal zenith at a more coronal position.\textsuperscript{[43]} Furthermore, peri-implant probing in SST cases had revealed healthy conditions and volumetric analysis had shown a low degree of contour changes with effective preservation of facial tissue contours.\textsuperscript{[11]} The better periodontal environment in the SST group is due to the better preservation of the extraction socket with the criss-cross PDLs, thereby altering the immunity and bacterial invasion.\textsuperscript{[20]} This defense mechanism is lacking in the conventional technique as the implant is directly screwed into the alveolar bone. Healthy periodontium enhances the overall esthetics of implant restorations.

**Socket shield technique and patient satisfaction**

The success of treatment does not rely merely on the clinical and radiological evaluation; rather, it should also include patients’ perspective. Hinze et al.\textsuperscript{[20]} claimed their study to be the first reporting on patient assessed outcomes with SST. This outcome was measured with a visual analog scale (VAS), which showed that patients were highly satisfied with their treatment in terms of the reduced intraoperative discomfort and the postoperative pain and their improved ability to chew soft and hard foods. Xu et al.\textsuperscript{[27]} compared the patient satisfaction between the SST and conventional technique and found a significantly higher satisfaction in the SST group (VAS score = 9.08 ± 0.29) than the control group (VAS score = 8.77 ± 0.45). In the study by Yan et al.,\textsuperscript{[26]} of the 10 patients, 8 were satisfied with the overall treatment process, 2 were basically satisfied, and there was no general dissatisfaction 1 year postoperatively.

**Socket shield technique in comparison to conventional technique**

In the present review, 3 randomized controlled trials,\textsuperscript{[18,21,30]} 1 prospective nonrandomized controlled study\textsuperscript{[27]} and 2 comparative studies\textsuperscript{[14,28]} were included, which have compared the SST to the conventional technique of immediate implantation. Barakat et al.\textsuperscript{[15]} showed statistically significant higher horizontal and vertical bone loss in the conventional
technique as compared to SST. The decrease in mean probing depth was also statistically significant. This reduction of peri-implant probing depth is an indicative of improvement in the arrangement and density of collagen fibers around dental implants. The study by Bramanti et al.\(^\text{[21]}\) reported a higher esthetic outcome and better marginal bone level in SST cases. Sun et al.\(^\text{[20]}\) in their study also reported significantly lower values of loss in buccal plate width and height in the SST group, which indicated a greater bone loss in the control group. SST group patients had significantly lower values for probing depth, modified sulcus bleeding index, and modified plaque index at 12-month and 24-month follow-up examinations. The authors also reported slightly higher PES in the SST group, but it was not statistically significant. In the study by Xu et al.\(^\text{[27]}\) there was a statistically significant difference in the labial bone resorption after 1 year of implant placement between the test group (SST) and the control group (conventional technique) with test group having lesser bone resorption than the latter. The PES was also significantly higher in the SST group. In the comparative study by Tiwari et al.\(^\text{[28]}\) the labial bone loss at crest at 12-month follow-up was significantly lower in the SST group (0.03 ± 0.025 mm) when compared to the conventional technique (0.188 ± 0.013 mm). Abadzhiev et al.\(^\text{[14]}\) also concluded that the SST group had lesser bone loss, more soft-tissue volume, and better esthetic outcome when compared to the conventional technique. However, it is interesting to note that the implant survival rate in all these studies have been 100% in both the groups with no clinical complications except the study by Tiwari et al.\(^\text{[28]}\) where the implant survival and complications have not been reported. In addition to buccal plate preservation, the gingival biotype also plays a crucial role for the successful outcome of the implant-supported restoration. A thin gingival biotype or buccally positioned implants may lead to more frequent or severe facial mucosal recession.\(^\text{[44,45]}\) SST induced a remarkable reduction in the midfacial mucosal and mesial and distal papilla recession as compared to the conventional technique.\(^\text{[30]}\) Hence, it is clear that conventional technique may have similar implant survival rates when compared with SST, but the SST appears to be a promising technique to deliver better implant success as the preservation of bone, esthetics, and patient satisfaction are superior in SST.

**Modifications in socket shield technique**

There have been several modifications in the surgical technique of preparing the socket shield as compared to the classical method described by Hürzeler et al.\(^\text{[8]}\) Siormpas et al.\(^\text{[15]}\) renamed it as “Root membrane technique” as this term shifts the focus of this technique to the maintenance of the root fragment and the attached PDL. Gluckman et al.\(^\text{[19]}\) in a study proposed a modified SST by reducing the socket shield to bone crest level, creating a chamfer in the crestal 2 mm of the shield and providing a prosthetic space of 2–3 mm between the subgingival crown contour and the shield for soft-tissue infill. Han et al.\(^\text{[23]}\) reported 100% implant survival rate without any biological complications with modified SST by reducing the shield to a thickness of 1.5 mm with a concave profile, leaving the most coronal part of the root at bone crest level and placing no graft material in the space between the shield and the implant. A modified proximal shield technique\(^\text{[10,43]}\) for interdental papilla preservation also yielded good success by placing the shield more in the interproximal area than the buccal area. Troiano et al.\(^\text{[46]}\) proposed and achieved 100% implant success with Root-T-belt technique which involved implant placement using root remainders in the esthetic zone, to preserve all 360° of bone structure.

In the original technique by Hürzeler et al.\(^\text{[8]}\) the enamel matrix protein was administered on the inside of the root fragment before the placement of implants. Various graft materials have been used to fill the space between the implant and the shield-like xenograft mixed with platelet-rich in growth factors,\(^\text{[14]}\) bioactive glass-calciumphosphosilicate,\(^\text{[28]}\) Bio-Oss bone powder,\(^\text{[17,26,27]}\) allograft,\(^\text{[17,21]}\) and deproteinized bovine bone mineral.\(^\text{[20]}\) Yan et al.\(^\text{[26]}\) and Sun et al.\(^\text{[30]}\) used the grafts in the cases where the jumping distance between the shield and the implant was >1 mm, whereas Bramanti et al.\(^\text{[21]}\) and Xu et al.\(^\text{[27]}\) used the grafts in the cases where the jumping distance was ≥2 mm. Botticelli et al.\(^\text{[47]}\) concluded in an animal study that the bone grafts are indicated in cases where the space is >1 mm. According to Xu et al.,\(^\text{[27]}\) placement of a bone graft prevents crush injury of the socket shield and the labial bone plate during implant placement, avoids the complications caused by direct contact between the implant and the shield and reduces the technical sensitivity of the traditional SST. However, there are studies as well, where no grafts were placed.\(^\text{[15,22,23,25]}\) Kher et al.\(^\text{[25]}\) evaluated the clinical and radiographic outcomes of SST without the use of bone grafts and concluded that SST yielded successful results. Mitsias et al.\(^\text{[48]}\) presented human histologic evidence of root membrane technique after 5 years of function and reported that the implant showed osseointegration with the apical and medial third of the space between the implant and the shield filled with compact, mature bone, whereas the coronal third was colonized by noninfiltrated connective tissue. This good quality of bone is difficult to obtain with the use of grafting. Moreover, the grafting may pose a risk of infection and cause delayed healing. In fact, despite a large gap distance and without primary flap closure, a bone graft or a barrier membrane, the immediate implant placement

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1. Sharma, et al.: Socket shield technique for immediate implant placement
2. Hürzeler et al.: Reported 100% implant survival
3. Conventional technique
4. Animal study
5. Labial bone loss
6. Histologic evidence
7. SST technique
8. Bone grafting
9. Interproximal area
10. Root membrane technique
11. Root-T-belt technique
12. Enamel matrix protein
13. Xenograft
14. Bioactive glass-calciumphosphosilicate
15. Bio-Oss bone powder
16. Allograft
17. Deproteinized bovine bone mineral
18. SST with enamel matrix protein
19. Modified SST
20. Root-T-belt technique
21. Long-term outcomes
22. Crush injury
23. Bone quality
24. Immediate implant placement

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**Supplementary Information**

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in extraction sockets with an intact buccal wall shows bone healing and osseointegration.\textsuperscript{[19]} Avoiding the use of grafts also reduces the treatment cost. Although the treatment methods are different, the end results show that implant retention rate is high. Further researches are required to establish the correlation between the success rate of SST and the different treatment methods to fill the gap.

**CONCLUSION**

The success of implant treatment depends on the collective outcome and long term maintenance in terms of function, esthetics, and healthy peri-implant tissues. SST emerges as a treatment alternative which aims at preserving the alveolar bone by retaining a part of the natural tooth for better overall implant success. Within the limitations of this review and due to paucity of the currently available literature, it may be concluded that though the implant survival rate may be comparable in SST and the conventional technique, the SST seems to be performing better in terms of bone preservation, esthetic outcome, and patient satisfaction. Further randomized clinical trials are required to generate strong evidence for recommending SST over the conventional technique for long-lasting successful treatment outcomes with immediate implants.

The following recommendations may be useful for predictable clinical outcome of SST for immediate implant placement:

- It is a technique sensitive procedure. The case selection is critical and the surgical procedure should be performed by the expert clinicians
- A CBCT evaluation of the preparation site is very essential for preoperative evaluation of root anatomy and visualization of any possible apical infection, resorption, fenestration, and dehiscence
- The thickness of the shield should be at least 1.5 mm to ensure resistance to fracture and resorption
- Apex of the root should be completely removed, and it should be ensured there is no vertical fracture or mobility in the shield
- Tapered implants with knife-edge threads provide excellent implant stability
- Customized transgingival abutment or provisionalization with a screw-retained provisional restoration is preferred for a better emergence profile.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

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