A Review of the Application and Progress of the Socket Shield Technique in Implant Restoration

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The Socket Shield Technique (SST) is a method that aims to preserve the alveolar bone and reduce postextraction bone resorption by retaining part of the tooth root; despite significant advancements in immediate implant placement and bone regeneration techniques in implant dentistry, alveolar bone resorption after tooth extraction remains a major clinical challenge, with current methods failing to prevent bone remodeling completely. This review aims to summarize the application progress of SST in implant restoration, discuss its advantages and limitations, and analyze key issues in its clinical application. By reviewing the existing literature, we conclude that SST, as a considerable potential treatment approach, the effectiveness of SST is still influenced by factors such as the three-dimensional position of the tooth slice, bone graft materials, and surgical procedures. However, it offers significant benefits, including the effective preservation of bone resorption, reduction in the need for bone augmentation procedures, high implant survival rates, and favorable clinical outcomes. SST provides a potential therapeutic paradigm for immediate implant placement, offering significant clinical value and research significance.

Key Words: socket shield technique, alveolar bone loss, dental implants, tooth extraction, bone regeneration

INTRODUCTION

The inner wall of the alveolar socket is composed of porous, intrinsic alveolar bone arranged in a lamellar structure, also known as bundle bone, with a width of 0.2–0.4 mm, which forms a bundle bone-periodontal ligament-cementum complex through perforating fibers. Due to surgical trauma during tooth extraction, the absence of bundle bone and periodontal ligament, and lack of functional stimulation, alveolar bone resorption occurs after tooth extraction.[1–3] A systematic review by Van der Weijden et al[4] indicates an average reduction of 3.87 mm in alveolar bone width after tooth extraction in humans over 6 months, with an average height reduction of 2.57 mm. Notably, buccal plate resorption is usually more significant than the palatal side, as most dislocations occur buccally during tooth extraction. The buccal plate is thinner, especially in the maxillary anterior teeth, where most sites are $\leq$1 mm, with an average thickness of only 0.5 mm, and even 50% of sites are $\leq$0.5 mm.[5,6]

Researchers have attempted to halt the remodeling process of the alveolar bone after tooth extraction or promote tissue regeneration through flapless tooth extraction, immediate implantation, guided bone regeneration, and site preservation.[7] Animal experiments by Blanco et al[8] and Araújo and Lindhe[9] suggested that the horizontal and vertical changes in alveolar bone after 3 and 6 months of extraction were not remarkably related to whether a flap was raised during extraction. A systematic review by Lang et al[10] indicated that marginal bone loss persists within 1 year of immediate implantation; experiments with Beagle dogs by Araújo et al[3] revealed similar buccal-lingual bone wall heights in the immediate implantation and natural healing groups 3 months postextraction, suggesting that immediate implantation did not prevent the progression of bone resorption. In the meantime, guided bone regeneration can only compensate for part of the bone remodeling after extraction if performed simultaneously.[6] Additionally, Ten Heggeler et al[11] concluded that site preservation in nonmolar areas lacked sufficient clinical evidence and high-quality randomized controlled trials. Moreover, existing literature suggests a possible reduction in alveolar bone resorption without preventing this process, and complications such as membrane exposure and infection may also occur.[11] In conclusion, the above methods fail to completely control a range of remodeling processes due to tooth extraction.

The Socket Shield Technique (SST) was developed to address this challenge. Casey and Lauciello[12] first proposed preserving a portion of the tooth root as a submerged root to stimulate the bone in 1980 to prevent bone resorption and protect the alveolar bone after tooth extraction. The core concept of the submerged-root technique is to maintain the width and height of the alveolar bone by preserving the buccal tooth slice of the root, thereby reducing soft tissue recession and optimizing the aesthetic outcomes of the restoration. Although the submerged-root technique was initially designed to improve denture retention, with the progress of clinical research, it has gradually been applied to implant restoration and has influenced the development of SST. Hürzeler et al[13] modified the experimental protocol and proposed that implants could achieve good osseointegration without bone resorption after preserving the buccal tooth slice of the mandibular premolar root in Beagle dogs. This technique effectively avoids the bone remodeling process after tooth extraction by preserving the buccal tooth slice of the root during immediate implantation, significantly reducing the resorption of the buccal plate and maintaining the stability of both soft and hard tissues. Therefore,

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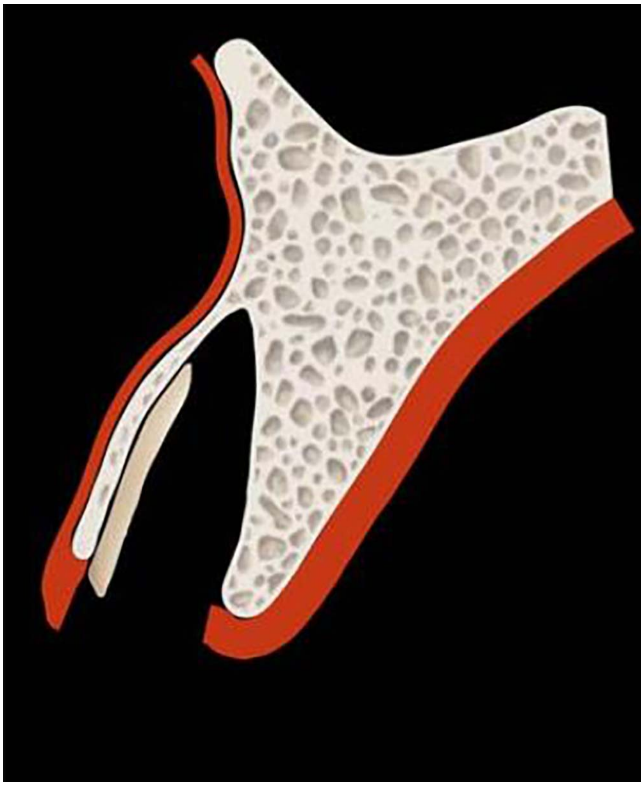

Figure. Dental schematic diagram.[34]

SST has been further validated as an effective treatment method that preserves the alveolar bone's integrity and avoids the bone resorption issue commonly encountered in traditional immediate implants (Figure).[14–17]

The basic principle of SST is to prevent bone resorption after tooth extraction by retaining a portion of the root, especially the buccal plate. Unlike traditional immediate implantation, SST maintains the natural shape of the alveolar bone by preserving a part of the natural tooth structure, reducing postoperative bone remodeling, and protecting soft tissue stability. This technique is considered a considerable potential approach for implant restoration that effectively avoids bone resorption and soft tissue recession in addition to improving the initial stability of the implant, boasting advantages including significantly reducing bone resorption after tooth extraction and maintaining the stability of the alveolar bone and soft tissues.[17] Research has shown that SST can prevent the resorption of the buccal plate and maintain the soft tissue profile by preserving the buccal tooth slice, thereby enhancing aesthetic outcomes and functional recovery after restoration.[13,16] Despite some success in clinical practice with this technique, its application still faces challenges, such as the selection of bone graft materials, the precise requirements for surgical operation, and the selection of indications. In this regard, the progress of SST in implant restoration, including its advantages, limitations, and key issues in its clinical application, is reviewed in this paper, to provide a potential therapeutic paradigm for immediate implant placement.

Data and Methods

Source of data

The search terms used were "Socket shield technique," with the scope limited to the title and abstract. Searches were conducted in the PubMed database (http://www.ncbi.nlm.nih.gov/pubmed). The types of literature retrieved included original articles, reviews, commentaries, case reports, books, and others. The search was conducted by the first author from January 2009 to December 2024.

Inclusion criteria

Inclusion Criteria: (1) Animal studies on socket shield technique; (2) Clinical applications of socket shield technique.

Exclusion Criteria: Duplicate studies.

Quality evaluation

A computer-based initial search retrieved 139 articles. Titles and abstracts were read for preliminary screening to exclude studies unrelated to the research topic or with duplicate content. A total of 29 articles that met the criteria were included, comprising eight systematic reviews include[12,15,17,19,29,31,34,35] two clinical controlled trials include.[18,32] fourteen case reports include [16,20,21,22,23,28,29,30,33,38,42,45,46,47] five animal experimental studies include.[13,27,36,37,39]

Clinical Use for SST

Indications and contraindications for SST

SST is suitable for teeth that are fractured due to trauma (fracture lines not reaching the underlying bone), teeth with caries that cannot be preserved, teeth requiring extraction due to failed root canal treatment, and teeth with intact buccal plates, particularly in the maxillary anterior region.[18–20] Meanwhile, SST is contraindicated in situations as follows: loose teeth; periodontal tissue disease; extensive periapical lesions or acute periapical lesions; root resorption; severely malpositioned teeth; and individuals with contraindications for implant surgery.[15,18,19]

SST treatment process

First, preoperative routine examinations were conducted to exclude surgical contraindications, with a CBCT scan taken to assess the condition of the alveolar bone and tooth roots. Next, the crown was sectioned at the level of the gingiva under local anesthesia, with the root split mesiodistally using a high-speed turbine handpiece and a C-shaped curvature prepared along the labial side. Then, the palatal tooth slice and apex were minimally invasively extracted, with inflammatory tissues completely removed by scratching the socket. Finally, the buccal tooth slice was trimmed to allow for a coronal edge of 1 mm above the alveolar bone crest (to preserve the gingival fibers and enhance soft tissue aesthetics), with a length equivalent to 2/3 of the tooth root and a thickness of about 1/2 of the distance from the canal wall to the buccal edge of the root, thereby avoiding sharp edges and maintaining a stable buccal tooth slice. Later, the implant was placed in an accurate 3-D position to ensure initial stability. Afterward, bone graft materials were placed in the jumping gaps between the tooth slice and the implant, in which an implant-supported temporary restoration was applied immediately if the Implant Stability Quotient (ISQ) $>$ 70, and a personalized healing abutment was screwed in to ensure adequate space for the soft tissue if the ISQ $<$ 70, to form an ideal S-shaped implant emergence profile and prevent epithelial cells from migrating into the extraction socket, followed by final restoration performed after 3-6 months of healing.[13,15,19,21]

Histological evidence

Mitsias et al[22] reported SST + immediate implantation for a case of a right maxillary lateral incisor that could not be preserved due to a horizontal crown fracture, and the patient suffered a maxillary bone fracture in a car accident 5 years after loading, making it necessary for the removal of the implant. Histological evidence indicated that the tooth slice and buccal plate were intact with no signs of resorption, with sufficient blood supply from the physiological periodontal ligament to the buccal plate. No bone graft materials were used in the space between the tooth slice and the implant, and connective tissue infiltration was observed between the coronal third of the tooth slice and the implant, with no inflammatory response. In contrast, the lower two-thirds of the tooth slice formed a dense osseointegration with the implant, showing mature bone tissue. However, Schwimer et al[23] reported a patient who underwent immediate implantation after the extraction of a left upper first premolar, with a mesiobuccal probing depth of 6 mm 2 years postoperatively, along with significant bone loss around the crown of the implant and suspected tooth slice images mesially on radiographs. This outcome differed from SST's, in which the latter could better preserve the buccal plate to avoid bone resorption and soft tissue recession, demonstrating its unique advantages. After the removal of the implant, the tooth slice was visibly attached to the mesial surface of the implant, with dentinal tubules and cementum structures observed in the tooth slice, confirming the presence of tooth root and the gap between the implant and the tooth slice, as well as the threads, was filled with mature bone tissue.

Classification of SST

Once a tooth is lost, the gingival papilla will retract due to the resorption of the alveolar bone in the interproximal area, thereby affecting the pink aesthetics of the restoration. A review by Roccuzzo et al[24] suggested that the distance from the top of the interproximal alveolar bone crest to the tooth contact area is closely correlated to the height of the gingival papilla, with a shorter distance indicating a higher probability of papilla fullness. Meanwhile, the stability of the peri-implant soft tissue is subject to the degree of papilla fullness, the periodontal biotype, and the width of the keratinized gingiva, and a reduction in papilla height indicates recession of the buccal mucosa.[25] In this regard, it is essential to preserve as much alveolar ridge as possible and maintain it at a stable level to achieve stable and healthy soft tissue in implant prosthetics. However, clinical conditions are constantly changing, with greater attention required to preserving hard and soft tissues in many complex situations, such as the inability to retain multiple consecutive residual roots, loss of teeth with adjacent residual roots, or the presence of implants. Therefore, SST can be classified into the following types according to different clinical scenarios:

Buccal Tooth Slice[19]

This is the earliest and most common type, in which the tooth slice ends at the interproximal angle of the natural tooth, and is suitable for single-tooth implants where the periodontal tissues of adjacent teeth are normal.

Interproximal Tooth Slice[19]

The tooth slice is located only in the interproximal area. It does not wrap around to the buccal side, suitable for cases with buccal plate resorption or when bone grafting is needed due to fenestration or fractures, especially when one or both adjacent teeth are nonnatural. Cherel and Etienne[26] reported a case with no retention value for two maxillary central incisors, in which the researcher retained the mesial parts of both roots to preserve the fullness of the mesial gingival papilla, effectively preserving the interproximal tooth slice and simultaneously implanted the implant with immediate restoration, with the mesial gingival papilla and the interproximal alveolar ridge found to be preserved entirely after completing the final restoration.

Half-C or Full-C Tooth Slice[19]

The tooth slice extends buccally into one or both interproximal areas, suitable for cases lacking natural teeth on one or both sides.

Lingual/Palatal Tooth Slice[19]

The tooth slice is located only on the lingual/palatal side, with fewer indications, and is primarily suitable for maxillary molars.

Buccal Multi-Tooth Slice[19]

There are 2 or more tooth slices buccally, suitable for longitudinal cleft labiolingual to the tooth root. Bäumer et al[27] was the first to propose the idea of alveolar bone preservation using two buccal tooth slices and validated it through experiments on Beagle dogs and clinical cases, expanding the indications for this technique. SST can also be considered for teeth with longitudinal cleft labiolingual to the root.

Pontic Type

Wong et al[28] described a method where nonretainable roots well treated with endodontic treatment were trimmed to the level of the alveolar bone crest, serving as the pontic area for the implant fixed bridge, with the soft and hard tissue contours being almost indistinguishable from those before extraction after 3 months of restoration. However, the root submergence technique is suitable for healthy pulp or teeth that have undergone complete root canal treatment and is contraindicated in cases of apical infection or failed pulp treatment. By contrast, Gluckman et al[29] reported preserving the buccal alveolar bone at the site using SST if the root was desired as the pontic area for an implant fixed bridge despite being unsuitable for submergence. The preliminary steps for preparing the tooth slice were the same, with bone graft materials implanted into the remaining extraction socket and the wound closed using a barrier membrane or soft tissue graft. Additionally, Esteve-Pardo and Esteve-Colomina[30] noted in a case of implant fixed bridge restoration that buccal tooth slices were retained in both the implant placement site and the pontic area, resulting in no remarkable changes in the contour and aesthetic performance of the buccal tissue compared with the preoperative natural tooth.

Complications

Gluckman et al[31] found that SST-associated complications included implant osseointegration failure, exposure and infection of the tooth slice, and displacement of the tooth slice, with the most common one being internal exposure of the tooth slice (toward the restoration), potentially due to sharp edges of the slice or insufficient distance between the slice and the crown. The second most common complication is external exposure of the tooth slice (toward the oral cavity), which may result from the slice being too sharp or extending too far toward the crown. Regardless of the type of exposure, minimally invasive adjustments should be made to round the edges of the slice, with soft tissue grafting adopted as needed. Applying a modified technique where the slice is level with the alveolar bone crest and forms a lingual slope can mitigate these complications. Siormpas et al,[32] in a 10-year follow-up, concluded the complications observed, including displacement of the tooth slice, loosening of the slice, infections, and caries due to slice exposure, and the coverage of the implant surface with cementum and periodontal ligament.

Additionally, Stuani et al[33] observed extensive low-density lesions around the implant apex 10 months after the tooth slice technique, speculating that this may be due to debris generated during the slice preparation or accumulation of root-filling materials around the implant apex. Moreover, other complications include peri-implant mucositis, peri-implantitis, soft tissue recession, and alveolar bone resorption.[34,35] Therefore, it is essential to carefully investigate the underlying causes and address them accordingly when complications occur.

Factors affecting the effectiveness of SST

Three-Dimensional Position of the Tooth Slice

In 2016, Calvo-Guirado et al[36] investigated the impact of different thicknesses of the tooth slice on bone remodeling in Beagle dogs. Histological evidence revealed that the slice was attached to the alveolar bone via physiological periodontal ligament, and newly formed bone tissues occupied the space between the slice and the implant. However, a marked increase was observed in postoperative bone remodeling and apical migration when the thickness of the slice exceeded 2 mm. Meanwhile, Tan et al[37] explored the effect of slice height on prognosis in 2018 and found that despite the significantly less probing depth in the group where the slice was level with the alveolar bone crest than the group where the slice was 1 mm above the crest, both groups exhibited similar vertical bone resorption and were less than the control group, with newly formed bone observed between the implants and the slices in both groups. In the meantime, the amount of bone resorption was negatively correlated with the slick thickness in the case of slice thickness of 0.5–1.5 mm, possibly related to heat generation and vibration during the surgical procedure. In 2018, Han et al[38] advocated for reducing the slick thickness to 1–1.5 mm, which is sufficient to ensure the strength and stability of the slice, and the crown of the slice should be level with the bone surface to reduce the risk of slice exposure while creating a lingual slope that provides space for soft tissue filling.[38] In 2019, Calvo-Guirado et al[39] investigated the effect of slice length on bone remodeling based on previous experiments, with all slices about 2 mm thick positioned at the level of the alveolar bone crest and divided into the crown 1/3, crown 2/3, and full-length groups based on the slice length, which revealed the least bone remodeling in the crown 1/3 group.

Bone Graft Materials

Botticelli et al[40] concluded that bone graft materials are required if the implant jumps over 1 mm from the buccal plate. This can prevent epithelial cells from invading, guide osteogenesis, and prevent adverse consequences due to buccal plate resorption. Histological findings by Hürzeler et al[13] showed the presence of newly formed dental cementum on the palatal surface of the slice and the implant surface, presumably related to enamel matrix derivatives. Specifically, enamel matrix proteins facilitate the proliferation and attachment of periodontal ligament fibroblasts, gingival fibroblasts, and epithelial cells, enhance the expression of osteoblast and odontoblast-related transcription factors, and also influence the expression of bone remodeling-related cytokines, leading to increased bone deposition and reduced bone resorption.[41] At the same time, Saeidi et al[42] reported satisfactory clinical and radiographic outcomes using enamel matrix proteins. Additionally, bone graft materials can be derived from various sources, including autogenous bone, allografts, xenografts, or synthetic materials, which at least have the function of osteoconduction and can serve as a scaffold for osteogenesis.

Tarnow and Chu[43] reported a case of immediate implantation with an intact buccal plate, where the jumping gap was 4.2 mm. Still, no bone graft materials or barrier membranes were used, with both clinical and histological examinations indicating successful implant osseointegration. Multiple studies support the nonuse of bone graft materials when using SST with an intact buccal plate. For example, histological findings from 3 animal studies[36,37,39] showed occupied space between the slice and the implant by mature newly formed bone tissue. In the meantime, 2 large-sample case studies[32,44] also confirmed satisfactory osseointegration for almost all implants through clinical and radiographic examinations.

Additionally, Mitsias et al[22] reported invisible connective tissue between the crown of the slice and the implant after 5 years of loading, without inflammatory infiltration, while high-quality newly formed bone tissue was observed in other areas. Moreover, Han et al[38] proposed a modified SST while advocating the nonuse of bone graft materials. Of course, the values of the jumping gaps were not specified in these studies.

Surgical Procedures

SST comes with high technique sensitivity, particularly during the root-splitting stages. To reduce the difficulty of the procedure, Bäumer et al[27] suggested directly preparing the implant socket palatally after coronectomy before removing the tooth root, which avoided the potential loosening or damage of the slice that may occur from vibrations and heat generation if the palatal and mesiodistal roots were removed first. Roe et al[45] performed a semicircular incision and fenestration of a full-thickness flap 5 mm from the root of the buccal gingival margin to expose the apex for better preparation of the buccal slice. However, this approach was invasive and led to scar tissue formation postoperatively. Chen et al[46] utilized intraoral scanning data and CBCT data to create a digital guide using CAD-CAM technology, which assisted in the intraoperative preparation of the slice, thereby reducing the surgical difficulty and shortening the operation time to some extent. Additionally, Chen[47] completed SST with the assistance of a dynamic navigation system, which allowed for real-time visualization of the alveolar bone, tooth roots, and essential anatomical structures compared with static surgical guides while enabling intraoperative adjustments to the treatment plan for safe and precise digital implantation, thereby making it suitable for the situations with limited surgical space.

Clinical applications

Gluckman et al[31] published a retrospective study with a 1- to 4-year follow-up involving 128 nonmolar implants, reporting an implant survival rate of 96.1%, with five implants removed due to osseointegration failure. Additionally, other complications, such as slice exposure (n = 16), slice loosening due to infection (n = 3), and slice displacement (n = 1), were also reported, which were managed symptomatically and did not affect the survival rate of the implants. In the meantime, another 5-year retrospective study,[40] focused solely on the maxillary anterior region, reported a 100% success rate for 46 implants and the respective resorption rates of 0.18 $\pm$ 0.09 mm and 0.21 $\pm$ 0.09 mm for the mesiodistal alveolar bone crest based on clinical and radiographic examinations, while only 1 patient, who was a smoker, experienced complications after 3 years of implant loading, with about 1.5 mm of root resorption of the slice observed while without any symptoms of implant failure. Subsequently, Siormpas et al[32] reported a retrospective study involving a total of 250 anterior teeth, with an average follow-up of 49.94 months and a maximum of 10 years, in which 5 implants were removed due to osseointegration failure (n = 2) and peri-implantitis (n = 3). Moreover, postrepair complications included slice infection (n = 5, of which 3 were associated with peri-implantitis), implant loosening (n = 2), and peri-implantitis (n = 1).

In summary, SST effectively preserved bone resorption, reduced the need for bone augmentation procedures, and demonstrated a high implant survival rate. Additionally, it exhibited favorable clinical outcomes with enhanced aesthetic results. However, the technique required a high level of surgical precision and was associated with certain risks of complications. While short- and medium-term outcomes were promising, further research and validation were necessary to assess its long-term effectiveness. Future studies will likely focus on refining surgical protocols, identifying optimal patient selection criteria, and evaluating long-term outcomes to further improve the technique's efficacy and applicability. Moreover, integrating advanced biomaterials and regenerative therapies enhanced SST's success rates, ultimately expanding its clinical application.

Limitation

The current research still comes with limitations. (1) SST requires high operational skills, which may pose technical challenges in certain clinical settings. (2) Further clarification is still required for the scope of indications and contraindications for SST, especially on selecting the appropriate patients and timing for surgery to maximize its advantages. (3) Despite several clinical studies having validated the effectiveness of SST, most studies utilize small sample sizes and lack long-term follow-up data. Therefore, more high-quality, randomized controlled trials are required to validate the effects of SST in long-term clinical applications.

Conclusion

SST has become an indispensable technique as a considerable potential approach to implant restoration due to its significant advantages in protecting the buccal bone plate, reducing bone resorption, and maintaining soft tissue stability. This article reviews the clinical application of SST in dental implants, covering its indications, treatment process, histological evidence, classification, complications, factors affecting effectiveness, and clinical applications.

SST is suitable for teeth that cannot be preserved, especially in the maxillary anterior region, where the integrity of the buccal plate needs to be maintained. The treatment process includes preoperative examinations, tooth sectioning, tooth slice and apex removal, and precise implant placement. Common complications of SST include implant failure and tooth slice exposure, which can be minimized with correct surgical techniques and patient care. The success of SST is influenced by factors such as the three-dimensional position of the tooth slice, bone graft materials, and surgical procedures.

Overall, SST offers significant advantages in implant survival rates and preserving bone tissue, but it also requires high-level surgical skills and carries certain risks. Future advances in biomaterials and regenerative therapies may further improve its success rate and broaden its clinical applications.

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