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Review article

Socket shield technique: A systemic review and meta-analysis

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Abstract

Purpose: The aim of the present study was to evaluate the clinical feasibility of the socket shield technique (SST).

Study selection: An electronic search of the PubMed, Cochrane Central Register of Controlled Trials, and Wiley Online Library databases, and a manual reference search for articles published up to September 2020 was conducted. Meta-analysis was performed to estimate marginal bone loss (MBL), changes in buccal bone width (cBBW), pink esthetic score (PES), implant stability quotient (ISQ), implant failure rate, and complication rate between SST and conventional immediate implant placement (IIP). All pooled analyses were based on random effects models.

Results: Sixteen relevant studies were ultimately selected by two independent reviewers: four randomized clinical trials (RCTs), four case-control studies, and eight retrospective studies. Meta-analysis revealed a trend toward lower MBL and cBBW and higher PES in the SST group. ISQ, implant failure rate, and complication rate were similar between the groups.

Conclusions: The included studies provided evidence that SST may be a feasible treatment option. However, this technique should not be used as a routine clinical protocol due to the lack of evidence-based consensus guidelines, large-scale RCTs, and long-term follow-up data. Therefore, there is an urgent need for well-conducted RCTs in this field.

Keywords: Socket shield technique, Aesthetic zone, Complication, Osseointegration

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1. Introduction

According to the published literature, the average thickness of the buccal bone width (BBW) in the anterior maxilla is < 1 mm, and almost 50% of BBW values are < 0.5 mm[1]. Therefore, such a thin facial bone wall, consisting mainly of bundle bone, appears to be prone to resorption following tooth extraction. The extent of bone resorption can be up to 2.6–4.5 mm and 0.4–3.9 mm in the horizontal and vertical directions, respectively, one year post-extraction[2].

Immediate implant placement (IIP) is becoming more popular among clinicians and patients owing to a reduction in surgery times, costs, and treatment cycles. Several studies have provided evidence that the success rate of IIP is similar to that of delayed implant placement[3,4]. However, some studies have found that IIP cannot prevent the absorption of alveolar bone and that it is associated with a higher frequency of soft tissue recession[3, 5–7].

To maintain soft and hard tissue contour and achieve long-term esthetic success, Hurzeler et al. published a proof-of-concept study of the socket shield technique (SST) in 2010[8]. This technique involves intentionally leaving a partial root membrane (RM) in the extraction socket during IIP. The authors reported a satisfactory outcome, given that no resorptive process in the BBW was noted and that implants were functionally loaded without any inflammation.

Since then, SST has become among the most controversial topics.

Although most published studies have supported the feasibility of SST, many are clinical case reports, with little reference value and insufficient guidance. Some reviews[9–11] have described complications, surgical details, and histological findings of SST; however, to the best of our knowledge, no recent meta-analysis evaluating this technique has been published. Therefore, the aim of the present systematic review and meta-analysis of the relevant literature was to test the null hypothesis that there are no differences between SST and conventional IIP.

2. Materials and methods

2.1. Objective

This systematic review adhered to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (i.e., PRISMA) statement and guidelines provided by the Cochrane Handbook for Systematic Reviews[12]. The focused question was elaborated using the PICO format (i.e., population, intervention, control, outcome) [13], as follows: population, patients who underwent implant placement; intervention, patients who underwent SST; control, patients who underwent conventional IIP; and outcome, primary outcomes included marginal bone loss (MBL) and changes in BBW (cBBW). The secondary outcomes were pink esthetic score (PES), implant stability quotient (ISQ), implant failure rate, and complication rate.

2.2. Search strategy

An electronic search of the PubMed, Cochrane Central Register of Controlled Trials, and Wiley Online Library databases was performed using specific search strings (Table 1), in addition to a manual search of the main implantology and periodontal journals, including *Clinical*

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Oral Implants Research, International Journal of Oral & Maxillofacial Implants, Clinical Implant Dentistry and Related Research, Journal of Clinical Periodontology, and Journal of Periodontology, the bibliographies of previous reviews, and all relevant articles. Personal references were also searched. The final update of the search was performed in September 2020.

2.3. Inclusion and exclusion criteria

Eligibility criteria included studies based on the socket-shield principle, in which implants are placed in close proximity to, or in contact with, RM intentionally retained to preserve or promote buccal/proximal/crestal bone. Article types included clinical human studies (either randomized or nonrandomized) that reported qualitative and quantitative parameters of MBL, cBBW, PES, ISQ, implant failure rate, and complication rate of SST and conventional IIP with no time restriction. Studies in which RM was not left intentionally to preserve or promote buccal/proximal/crestal bone, and implants were unintentionally placed in proximity or in contact with RM were excluded. Studies not published in English or Chinese, case reports, technical reports, finite element analyses, and review articles were also excluded.

2.4. Quality assessment

The included studies were independently screened by two examiners (XL and XHZ). The titles and abstracts of all studies retrieved in the online search were first scanned. The full-text of studies that fulfilled the inclusion criteria were then obtained. Full-text versions of studies that did not report sufficient data in the title and abstract needed to make a clear decision regarding fulfillment of the inclusion criteria were also obtained. Disagreements were resolved by discussion between the examiners. Kappa scores were determined to evaluate the level of inter-reviewer agreement.

The Cochrane Collaboration Risk of Bias tool was used to assess the risk of bias in randomized clinical trials (RCTs). “High risk of bias,” “low risk of bias,” or “unclear risk of bias” was assigned to each assessment item. The Joanna Briggs Institute (JBI) Critical Appraisal Checklist tool[14] was used to assess the quality of nonrandomized studies. Each component was rated as “yes,” “no,” “unclear,” or “not applicable.” The risk of bias classification was high, moderate, and low, corresponding to scores of 1–3, 4–6, and 7–8, respectively.

2.5. Data analysis

The primary outcomes assessed included MBL and cBBW. MBL was measured from the implant platform to the most crestal contact point between the implant and bone; cBBW was measured 0 mm from the crest. MBL and cBBW reflect bone changes in the vertical and horizontal directions, respectively.

Secondary outcomes included PES, ISQ, implant failure rate, and complication rate. PES is based on seven variables, each of which was assessed using a 2-1-0 score, with 2 being the best and 0 the poorest [15]. ISQ values were used as indicators of mechanical implant stability. They were obtained noninvasively using resonance frequency measurements. Theoretically, higher mechanical stiffness of the bone–implant interface is represented by higher ISQ value[16].

Complications included biological and mechanical complications. Biological complications are characterized by a process(es) that affects hard and/or soft tissues; technical complications include mechanical damage to the implant and its suprastructures. Implant failure included failure of osseointegration and fracture of the implant. For all categories, the number of events was recorded.

MBL, cBBW, and PES were divided into two subgroups according to the observation time period; more specifically, 6 months and 12 months post-surgery. ISQ was measured and analyzed at two time points: immediately after surgery and before final restoration. Implant failure and complication rates were calculated as the implant-base level.

Table 1. Search Strategy.

Database	Search Strategy	Results
Pubmed	((("socket shield") OR ("root membrane")) OR ("residual root")) OR ("retained root")) OR ("root fragment") AND ((implant) OR ("ridge preservation")) OR ("guided bone regeneration")	106
Cochrane Central Register of Controlled Trials	"socket shield" in All Text OR "root membrane" in All Text OR "retained root" in All Text OR "root fragment" in All Text OR "residual root" in All Text AND "implant" in All Text OR "ridge preservation" in All Text OR "guided bone regeneration" in All Text	41
Wiley online library	""socket shield" OR "root membrane" OR "retained root" OR "root fragment" OR "residual root"" anywhere and "implant OR " ridge preservation" OR "guided bone regeneration"" anywhere	469

2.6. Data analysis

Two of the authors (XL and XHZ) also performed data synthesis. The following data were extracted from the articles included in the current study: year of publication; study type; patient and implant size; implant site and details; details regarding the type of intervention; details regarding the outcomes reported; and follow-up period.

The meta-analysis was performed using Review Manager version 5.3.2 (The Nordic Cochrane Center, The Cochrane Collaboration, Copenhagen, Denmark, 2014). Due to the small number of articles, publication bias could not be assessed via funnel plots; as such, forest plots were formulated to report the outcome. MBL, cBBW, PES, and ISQ are expressed as mean difference (MD) with corresponding 95% confidence interval (CI) using the random effects model. Complication and implant failure rates were recorded as dichotomous outcomes, and expressed as risk ratio (RR) with corresponding 95% CI under the random effects model. Differences with $P < 0.05$ were considered to be statistically significant. The I^2 statistic was used to express the percentage of total variation across studies due to heterogeneity, with 25% corresponding to low heterogeneity, 50% to moderate heterogeneity, and 75% to high heterogeneity.

3. Results

3.1. Study characteristics

A total of 616 articles were retrieved in the initial search, as shown in Fig. 1. The identification of duplicates and articles not related to the topic resulted in the removal of 479 studies ($\text{kappa} = 0.75$). A review of the remaining titles, abstracts, and full-texts resulted 16 articles that were analyzed in the present study. There were four RCTs[17–20], four case-control studies (CCSs)[21–24], and eight retrospective studies (RSs)[25–32].

3.2. Risk of bias assessment of the included studies

A summary of the Cochrane Collaboration assessment of the four human RCTs is presented in Table 2. One study[17] was considered to have a lower risk of bias than the other three[18–20]. Among non-RCTs, one CCS[23] and one RS[29] were considered to have a moderate risk of bias, while the other nine were considered to have a low risk of bias (Table 3). More details are provided in Appendix 1.

3.3. Characteristics and outcomes of the clinical studies

The clinical characteristics reported in the included studies are summarized in Table 4. For studies that only provided the clinical outcome of the SST group, a total of 511 implants (428 patients) were examined, with a maximum follow-up period of 10 years. Eight studies[17–24] that provided comparable clinical data for the SST group and conventional IIP group were included in the meta-analysis: 115 implants (111 patients) in the SST group; and 119 implants (117 patients) in the IIP group.

Fig. 1. Flowchart of selected and excluded studies for systematic review.

Table 2. Cochrane Collaboration's tool for assessing risk of bias of included human randomized clinical trials.

	Study design	Selection bias		Free of performance bias	Free of detection bias	Free of attrition bias	Free of exporting bias	Free of Other bias
		Random sequence generation	Allocation concealment					
Dalia 2017 ^[20]	RCT	Unclear	Unclear	Unclear	Unclear	Low	Low	Unclear
Bramaiti 2018 ^[17]	RCT	Low	Low	Low	Low	Low	Low	Unclear
Sun 2019 ^[18]	RCT	Low	Unclear	Unclear	Unclear	Low	Low	Unclear
Ahmed 2020 ^[19]	RCT	Unclear	Low	Unclear	Unclear	Low	Low	Unclear

Table 3. The JBI critical appraisal checklist for assessing the quality of nonrandomized studies.

Name	Were there clear criteria for inclusion in the case series?	Was the condition measured in a standard, reliable way for all participants included in the case series?	Were valid methods used for identification of the condition for all participants included in the case series?	Did the case series have consecutive inclusion of participants?	Did the case series have complete inclusion of participants?	Was there clear reporting of the demographics of the participants in the study?	Was there clear reporting of clinical information of the participants?	Were the outcomes or follow-up results of cases clearly reported?	Was there clear reporting of the presenting site demographic information?	Was statistical analysis appropriate?	Risk of bias
Hesham 2018 ^[22]	Yes	Yes	Yes	Yes	Unclear	Unclear	No	Yes	Yes	Yes	low
Shamita 2019 ^[23]	Yes	Yes	Yes	Unclear	Unclear	No	No	Yes	Yes	Yes	moderate
Xu 2019 ^[21]	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	low
Sandy 2020 ^[24]	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	Yes	No	Yes	low
Baumer 2017 ^[27]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	low
Zhu 2018 ^[32]	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	low
Yan 2019 ^[25]	Yes	Yes	Yes	Yes	Unclear	No	Yes	Yes	Yes	Yes	low
Han 2018 ^[26]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	low
Hinze 2018 ^[28]	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	No	Yes	low
Siormpas 2014 ^[29]	Yes	Yes	Yes	Unclear	Unclear	No	Yes	Yes	No	Yes	moderate
Siormpas 2018 ^[30]	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	low
Gluckman 2017 ^[31]	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	No	Yes	low

The majority of studies included only the maxillary anterior region; however, three[26, 30–31] also included mandibular anterior sites. Eleven of 16 studies did not report gingiva biotype, while three did not limit the biotype[19, 26–27], and two recruited cases with a thick biotype[18, 21]. Eight studies[18, 19, 20, 22, 24, 26, 28, 30] accepted light smokers (≤ 10 cigarettes/day).

All of the included studies left RM on the buccal side, and the thickness of RM ranged from 1 to 3 mm, depending on the study. None of the included studies reported RM length. RM margins were mainly divided into three levels: 1 mm above the bone level[18, 21–22, 27–30]; bone level[19, 24–25, 31]; and 1 mm under bone level[17]. One study reported using an enamel matrix derivative[27] to prepare the RM. Six studies reported using bone graft materials to fill gaps between implants and RM[17–18, 21–22, 25, 27], and five clearly reported that no graft was used to fill the gap[24, 26, 29, 30, 32].

A variety of implant brands were used in the included studies, including Thommen (Grenchen, Switzerland), MegaGen (Daegu, Korea), Straumann (Basel, Switzerland), Nobel Biocare (Zurich, Switzerland), Osstem (Seoul, Korea), Dentium (Cypress, CA, USA), Ankylos (Dentsply Sirona, York, PA, USA), Dual Implant (Titan Industries EG, Cairo, Egypt), and Euroteknika (Sallanches, France). The diameter and length of the implants varied among the studies. Eleven studies used non-functional immediate loading after surgery[17–19, 21, 22, 24, 26, 28–30, 32], three used delayed loading[20, 23, 25], and a single study used both[27]. The time from surgery to final restoration ranged from 2 to 6 months.

The most frequently reported complication was RM exposure [19, 24, 31, 32]. Other complications included implant failure[24, 30, 31], RM migration[31], RM resorption[29], and infection[30, 31]. The clinical outcomes are summarized in Table 5.

3.4. META-ANALYSIS

3.4.1. MBL

Overall, there was a trend toward lower MBL in the SST group: total, mean difference (MD) -0.44 (95% CI -0.56 to -0.31), $P < 0.0001$, $I^2 = 75\%$; 6 months post-surgery, MD -0.46 (95% CI -0.62 to -0.30), $P < 0.00001$, $I^2 = 80\%$ (Fig. 2).

3.4.2. cBBW

Results of meta-analysis revealed that the SST group preserved the buccal bone profile better than the IIP group: total, MD -0.19 (95% CI -0.25 to -0.13), $P < 0.00001$, $I^2 = 88\%$; 6 months post-surgery, MD -0.17 (95% CI -0.24 to -0.10), $P = 0.01$, $I^2 = 78\%$; and 12 months post-surgery, MD -0.47 (95% CI -1.11 to 0.17), $P < 0.00001$, $I^2 = 96\%$ (Fig. 3).

3.4.3. PES

Meta-analysis revealed higher PES in the SST group: total, MD 1.44 (95% CI 0.80–2.07), $P < 0.00001$, $I^2 = 82\%$; 6 months post-surgery, MD 1.42 (95% CI 0.28–2.57), $P < 0.0001$, $I^2 = 87\%$; and 12 months post-surgery: MD 1.44 (95% CI 0.60–2.27), $P = 0.001$, $I^2 = 81\%$ (Fig. 4).

3.4.4. ISQ

Both groups demonstrated good ISQ immediately after surgery and before final restoration, which facilitated suitability for immediate restoration and sufficient stability to accept final crown delivery: total, MD 1.92 (95% CI 0.19–3.66), $P = 0.09$, $I^2 = 51\%$; immediately after surgery, MD 1.90 (95% CI -0.80–4.59), $P = 0.08$, $I^2 = 61\%$; and before final restoration, MD 2.34 (95% CI 0.20–4.48), $P = 0.32$, $I^2 = 1\%$ (Fig. 5).

3.4.5. Implant failure and complications

Only one CCS [24] reported two implant failures (one in the SST group and one in the IIP group); as a result, only one study was analyzed. Both the SST and IIP groups exhibited low implant failure (Fig. 6) and complication (Fig. 7) rates. The difference was not significant between the groups (implant failure rate, RR 1.00 [95% CI 0.07–14.90];

complication rate, RR 0.68 [95% CI 0.18–2.54]; $P = 0.56$; $I^2 = 9\%$).

4. Discussion

In meta-analyses, the potential of bias is likely to be greater for non-randomized CCSs than for RCTs. However, excluding the results from non-randomized studies would likely miss some important data[33]. To establish a solid foundation for causal inferences, therefore, additional data from non-randomized studies were included in the current study.

Based on findings from the current study, the implant survival rate in the SST group ranged from 97.3% to 100%, and the incidence of complications varied from 0% to 19.5%, which is similar to that of implant-supported single crowns after 5 years of functioning. Most implant failures and complications were reported in studies by Siormpas et al.[30] and Gluckman et al.[31]. These two studies included large cohorts with a long-term follow-up period of up to 10 years, thereby supporting the long-term success of SST.

Clinicians have attempted every method to prevent MBL and decrease absorption of the buccal bone plate[34–35]. The buccal bone-periodontal ligament (BB-PDL) complex is considered to be very important for maintaining alveolar ridge contour. When the tooth is extracted, this structure disappears, resulting in collapse of the residual bone tissue[36]. The present meta-analysis confirmed the hypothesis that implants treated with SST achieve a better and more stable hard profile compared with conventional IIP. Comparison of the included studies demonstrated a total of 0.44 mm less MBL and 0.19 mm less cBBW for implants treated with SST. A large number of animal studies and histological findings have shown that the BB-PDL complex could be well preserved using SST because the blood supply stemming from the periodontal ligament maintains buccal bone dynamics and contributes to long-term stability[37, 38]. PDL also plays an important role in biological sealing. Once the natural PDL is missing, the defense mechanism around the implant is weakened, and there is a higher risk for bacterial invasion and subsequent bone resorption[39, 40].

For esthetic assessment, hard tissue features, crown profile, and peri-implant soft tissue stability should be considered. However, peri-implant soft tissue presents clinical challenges from an esthetic perspective. The most common reasons for esthetic failure include disharmonious mucosal color or texture, loss of interproximal papillae, and recession of the soft tissue level. Hence, soft tissue esthetic outcomes are of vital importance for achieving clinical esthetic success. The PES is an objective system for evaluating peri-implant soft tissues[15, 41]. The system is based on seven variables—namely, mesial and distal papilla, the level of soft tissue margin, the contour, color, and texture of the soft tissue, as well as the alveolar process deficiency. The highest possible score reflecting a perfect match of the peri-implant soft tissue with that of the reference tooth is 14. In terms of the present study, the SST group exhibited a high PES, with an average of 11–13 points, which was 1.42–1.44 points greater than that of the IIP group at 6 and 12 months after surgery, respectively. Because soft tissue contour mainly depends on the underlying anatomy, stable PES further confirmed the contribution of RM.

It is crucial to isolate the implant from the oral cavity; thus, non-submerged healing is necessary for both SST and IIP. Constructing a customized healing abutment or anatomical provisional crown is required. Because bone-implant contact is reduced in a fresh extraction socket, an adequate surgical protocol for achieving primary implant stability is fundamental. Currently, ISQ is often used to measure primary implant stability[16, 42]. From our investigation, both groups exhibited good ISQ immediately after surgery, thus indicating suitability for immediate restoration. Intraoperative ISQ in the SST group was slightly greater than that of the IIP group (mean, 1.90), suggesting that the presence of RM did not influence primary stability. After several months of healing, implant stability—which is first achieved from mechanical stability—progresses to biological stability. Increased ISQ indicates successful osseointegration.

Although SST is no longer considered to be an experimental technique, many aspects should be interpreted with caution. First, a clear consensus protocol for SST is lacking. There are numerous reasons for tooth extraction. In most of the included studies, for SST, the root did not have a

Table 4. Characteristics of the included studies.

Name	Study type	Case of SST group (Patient /implant)	Case of IIP group (Patient /implant)	age (y)	Area	Inclusion for smokers	Gingiva biotype	Implant	Implant size (mm)	Graft material	Position of RM	RM preparation	Immediate loading	Final restoration time (m)	Follow-up (m)
Dalia 2017 ^[20]	RCT	10,10	10,10	Mean 35	MA	Yes	NM	Dentium	D:3.3-4.3 L:10-14	NM	Buccal	NM	No	4	7
Bramaiti 2018 ^[17]	RCT	20,20	20,20	NM	MA	No	NM	NM	D:4.5	CopiOs	Buccal	1mm sub crest	Yes	6	36
Sun 2019 ^[18]	RCT	15,15	15,15	≥25	MA	Yes	Thick	Nobel	NM	Bio-Oss (gap≥1mm)	Buccal	1mm above bone crest	Yes	6	24
Ahmed 2020 ^[19]	RCT	16,20	18,20	21-39 Mean:30.9	MA	Yes	No limit	Dual	D:3.3-3.7; L:14-16	NM	Buccal	to the level of bone crest	Yes	6	6
Hesham 2018 ^[22]	CCS	10,10	10,10	≥18	MA	Yes	NM	NM	NM	Bio-Oss (gap≥2mm)	Buccal	1mm above bone crest	Yes	6	12
Shamita 2019 ^[23]	CCS	8,8	8,8	18-30	MA	NM	NM	NM	NM	NM	Buccal	Subgingival level	No	4	12
Xu 2019 ^[21]	CCS	12,12	12,12	25-53 Mean:38.0	MA	No	Thick	Nobel, Osstem	NM	Bio-Oss (gap≥2mm)	Buccal	1mm above bone crest	Yes	6	12
Sandy 2020 ^[24]	CCS	20,20	20,20	28-65 Mean:51	MA	Yes	NM	Euroteknika	D:3.5-5.0 L:11-14	No	Buccal	2mm thick; to the level of bone crest	Yes	3	12
Baumer 2017 ^[27]	RS	10,10	No	≥25	MA	No	No limit	Thommen	NA	DBBM	Buccal	2-3mm thick; 1mm above bone level	6(Yes) 4(No)	5	60
Zhu 2018 ^[32]	RS	9,10	No	27-62	MA	NM	NM	Thommen, Ankylos	D:3.5-5.0 L:11-14	No	Buccal	1mm thick, 4mm long; 1mm above bone crest	Yes	3	12-48
Hinze 2018 ^[28]	RS	15,17	No	26-65 Mean:49	MAMB	Yes	NM	Thommen	NM	NM	Buccal	1-2mm thick; 1mm above bone crest	Yes	4	3
Han 2018 ^[26]	RS	30,40	No	20-82 Mean 48	MADA	Yes	No limit	Anyridge	D:3.5-5.5 L:7-13	No	Buccal	≥1.5 mm thick	Yes	12	12
Yan 2019 ^[25]	RS	10,10	No	18-48	MA	No	NM	Straumann, Osstem, Nobel, Dentium MegaGen	D:3.3-4.1 L:11.5-14	Bio-Oss (gap≥1mm)	Buccal	≥1.5 mm thick; to the level of bone crest	No	6	12
Siormpas 2014 ^[29]	RS	46,46	No	28-70 Mean:53	MA	NM	NM	MegaGen	D:4-5 L:10-15	No	Buccal	1mm thick, 1mm above bone crest	Yes	3	60
Siormpas 2018 ^[30]	RS	182,250	No	18-83 Mean:53.5	MA DA	Yes	NM	MegaGen	D:3.3-5.0 L:8,5-15	No	Buccal	1mm above bone crest	Yes	2-3	120
Gluckman 2017 ^[31]	RS	128,128	No	24-71 Mean:39	MA DA	NM	NM	MegaGen, Ankylos, Nobel	NM	NM	Buccal	to the level of bone crest	NM	NM	48

RS retrospective study; CCS case-control study; RCT randomized controlled trial;

MA: maxillary anterior; DA: mandibular anterior; MB: maxillary bicuspid

D: Diameter; L: length; RM: root membrane; NM not mention.

vertical fracture on the buccal side, and the subcrest horizontal fracture was also not allowed. Apical endodontic pathology is not an absolute contraindication. However, if the interface between the RM and implant is not thoroughly decontaminated, endotoxins, inflammatory cells, and bacterial deposits may become a potential source of infection and evoke an inflammatory response in the short or long term. No consensus statement has been published regarding the ideal RM dimensions in terms of length, thickness, or margin. Moreover, there is no consensus regarding the possible need to fill the gap with bone graft material nor the type of bone graft material suitable/optimal for SST. Second, the technique needs to be safe and repeatable because an inexperienced surgeon may produce adverse results and obscure the evaluation of its performance. The surgeon needs to be specially trained and possess a high degree of clinical skill because the surgical procedure requires more time and patience. Finally, although implant failure and complication rates were low in the current meta-analysis, some studies[43,44] have reported a case series documenting late implant complications and failures after 4–10 years of loading, which indicates the potential long-term risks of SST. Complications such as

RM migration, exposure, or inflammation may lead to soft tissue defects, pocket formation, mucositis, and peri-implantitis. This may also lead to severe esthetic problems such as discoloration and recession of the soft tissues[30, 31, 45-47].

Despite the comprehensive data synthesis and extraction performed in the present study, some limitations should not be neglected. Due to the small number of articles, publication bias could not be assessed via funnel plots; thus, it is not known whether studies with a negative outcome may have altered the outcome. There were many differences among the included studies, such as differences in preparation of RM, gingiva biotype, and loading protocol, which may have led to heterogeneity in some outcomes. It was not possible to discriminate these factors for a more individualized analysis, and these confounding factors may possibly represent an obstruction to the true outcome. However, the number of available RCTs is limited, and most of the included studies reported a small number of cases with short follow-up periods. Only a few studies reported adverse effects or complications. Therefore, it is still recommended that SST not be used as a routine clinical protocol because the procedure is technique-sensitive and

Table 5. Clinical outcome of included studies.

Name	Implant survival rate	Complication rate	Complication(case)	MBL (mm)	cBBW (mm)	PES	ISQ	Soft tissue recession(mm)
Dalia 2017 ^[20]	Both 100%	Both 0%	No	7m AS SST:0.44±0.24 ; IIP:1.61±0.78 ;	7m AS SST:0.10±0.03 ; IIP:0.34±0.11;	NM	Immediate AS SST:60.3±6.43 ; IIP:57.2±9.15 ; 4m AS SST:69.8±3.77 ; IIP:65.6±5.66 ;	NM
Bramaiti 2018 ^[17]	Both 100%	Both 0%	No	6m AS SST:0.54±0.055 ; IIP : 1.015±0.098 ;	NM	6m AS SST:12.3±0.86 ; IIP : 11.05±1.53 ;	NM	NM
Sun 2019 ^[18]	Both 100%	Both 0%	No	Not clear	Not clear	6m AS SST:12.00±1.77 IIP:11.73±1.67; 12m AS SST:12.20±1.57 IIP:11.53±1.73	Immediate AS SST:76.01±1.31 IIP:75.56±1.07	6m AS SST:0.3±0.07; IIP:0.87±0.19; 12m AS SST:0.59±0.09; IIP:1.09±0.22;
Ahmed 2020 ^[19]	Both 100%	SST: 5% IIP:0%	SST:RM internal exposure (1)	6m AS SST:0.34±0.12 IIP:0.77±0.35	6m AS SST:0.12±0.07 IIP:0.28±0.15	6m AS SST:12±1.12 IIP:8.85±1.51	Immediate AS SST:68.6±3.81 IIP:66.4±5.64 6m AS SST:76.7±3.49 IIP:75.0±4.4	NM
Hesham 2018 ^[22]	Both 100%	Both 0%	NM	6m AS SST:0.639±0.116; IIP:0.979±0.169; 12m AS SST:0.693±0.109; IIP:1.064±0.240	NM	6m AS SST:11.2±0.92; IIP:10.3±0.48; 12m AS SST:11.1±0.74; IIP:10.2±0.42	NM	NM
Shamita 2019 ^[23]	NM	NM	NM	NM	8m AS SST:0.03±0.025 IIP:0.156±0.029 12m AS SST:0.03±0.025 IIP:0.188±0.013	NM	NM	NM
Xu 2019 ^[21]	Both 100%	Both 0%	No	NM	12m AS SST:0.04±0.13 IIP:0.85±0.45	12m AS SST:13.25±0.75 ; IIP:11.83±0.94	NM	NM
Sandy 2020 ^[24]	SST:95% IIP:95%	SST:15% IIP:30%	SST: RM exposure (2), implant failure (1) IIP: soft tissue recession (5), implant failure (1)	NM	NM	12m AS SST:12.26±1.04 ; IIP:9.63±1.34	NM	NM
Hinze 2018 ^[28]	100%	0%	No	NM	NM	NM	NM	3m AS -0.07±0.16
Yan 2019 ^[25]	100%	0%	No	NM	12m AS 2.83±0.67	12m AS 9.1±0.54	NM	NM
Zhu 2018 ^[22]	100%	10%	RM external exposure (1)	Mesial 0.17, Distal 0.22	NM	13.5	NM	NM
Han 2018 ^[26]	100%	0%	No	NM	NM	NM	Immediate AS 72.9±5.9 12m AS 74.6±2.7	NM
Baumer 2017 ^[27]	100%	0%	No	Mesial 0.33±0.43, Distal 0.17±0.36	NM	12	NM	-0.33±0.23
Siompas 2014 ^[29]	100%	2%	RM resorption (1)	NM	NM	NM	NM	NM
Gluckman 2017 ^[31]	96%	19.50%	Implant failure (5); infection (3); RM exposure (16); RM migration (1);	NM	NM	NM	NM	NM
Siompas 2018 ^[30]	97.30%	11.50%	Implant failure (5); infection (5);	NM	NM	NM	NM	NM

NM: not mention. AS after surgery

Fig. 2. Forest plot for the event 'marginal bone loss (MBL)'.

Fig. 3. Forest plot for the event 'changes in buccal bone width (cBBW)'.

Fig. 4. Forest plot for the event 'pink esthetic score (PES)'.

Fig. 5. Forest plot for the event 'implant stability quotient (ISQ)'.

Fig. 6. Forest plot for the event 'implant failure'.

Fig. 7. Forest plot for the event 'complication'.

there is a lack of evidence-based consensus. There is, therefore, an urgent need for further studies with higher levels of evidence in this area.

5. Conclusion

The included studies provided evidence that SST may be a feasible treatment option. Nevertheless, this technique should not be used as a routine clinical protocol due to its sensitivity and lack of evidence-based consensus conclusions. There is an urgent need for additional studies in this area to provide higher levels of evidence.

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