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SCIENCE BEHIND THE SOCKET-SHIELD TECHNIQUE: ANALYTICAL LITERATURE REVIEW

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Trabalho apresentado à Universidade Fernando Pessoa como parte dos requisitos para a obtenção do grau de Mestre em Medicina Dentária.

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Chantal Cherine Clémence FARHAT

ACKNOWLEDGEMENT

I dreamt of graduating for the second time in my life from the dental school and this time not to be a dentist since am already a dentist, but to start a new life for me and for me beloved two princesses. As I fulfill my dream today, I accompany it with this acknowledgment.

*Foremost, I am extremely thankful to the merciful, supreme **God**, whose divine wings wrapped me with guidance and supplied me with unlimited consistency. Without his grace, this dissertation wouldn't have become a reality.*

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*I grab the opportunity to give a special thanks to my **family** members who were the pioneers to support me since the very beginning. Their eyes were full of concern constantly guiding and pointing the way.*

DEDICATION

It is my authentic gratefulness and warmest esteem that I dedicate this work to ***God*** *who guided me through these last years and in my entire life.*

Besides, I hallow this dissertation to my ***family*** *to pay them my genuine tribute and show my devotion as they assisted me to pursuit my goal.* ***Mom*** *and* ***Dad****, it cannot be neglected that I was really protected by your prayers and guidance and that without your help I wouldn't be able to achieve this today. I would say sorry for every unintentional shortening and inadvertent dereliction.*

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ABSTRACT

Introduction: Preserving the periodontal apparatus was a growing concept to save the buccal bone through protecting the blood supply to the area. However, tooth loss is inevitable and so is buccal bone dimensional changes. Here came the partial extraction therapies to better manage the devastating functional and esthetic consequences of tooth extraction.

Objectives: Thirteen years have passed since socket-shield technique, the most recent among those therapies, had been introduced to the spectrum of implant dentistry. Science behind, evidence of the technique, advantages and disadvantages, complications, technique modifications and long-term follow up are being introduced to the bulk of knowledge with time. The aim of this dissertation is to illustrate as clearly as possible, but also to evaluate, the utmost available information about socket-shield technique through a literature review.

Material and methods: Through a bibliographic search conducted on PubMed database , Web of Science, and Google Schola, we have selected a total of 34 articles over 288 positive results. The included articles are published between January 1990 and February 2020. A descriptive and analytical study of the data is carried out to examines the available evidence regarding the partial extraction and especially the socket-shield technique.

Results: Socket-Shield Technique showed great performance regarding esthetics and function, but, many technical limitations not be ignored, were extracted from the articles , leading to absolutely end up in failures at different aspects whether technical, functional, or esthetical, ; the results of the bibliographic review point also on the very limited follow-up periods come that with the case reports and series, that form in fact the majority of the bulk of knowledge about SST, and they are considered untrustworthy to predict the long-term prognosis of SST.

Conclusions: In conclusion, although it is evident that a great consensus about the clinical and esthetic success of SST has been earned, there is a greater unanimity among authors that the aforementioned technique still requires long-term clinical follow-up

Keywords: Partial extraction, Post-extraction alveolar resorption, Dental implants, Socket-shield, Root-membrane, Bone preservation, Root submersion.

CONTENTS

LIST OF ABBREVIATIONS

BB-PDL: bundle bone-periodontal ligament complex

BPH: buccal plate height

BPW: buccal plate width

B-SEM: backscatter detector of a scanning electron microscope

CAD-CAM: computer-aided design and computer-aided manufacturing

CBCT: cone beam computed tomography

CTG: connective tissue graft

GBR: guided bone regeneration

IIP: immediate implant placement

ISQ: implant stability quotient

LM: light microscope

MBL: marginal bone level

mPI: modified plaque index

mSBI: modified sulcus bleeding index

MSST: modified socket-shield technique

PD: probing depth

PDL: periodontal ligaments

PES: pink esthetic score/scale

PET: partial extraction therapies

PRF: platelet-rich fibrin

RST: root submergence technique

RCT: randomized controlled trial

RMT: root membrane technique

PST: pontic-shield technique

SST: socket-shield technique

3D: three-dimensional

1. INTRODUCTION

While the fact of post-extraction alveolar ridge resorption has taken a great worldwide consensus, the solutions for this three-dimensional (3D) hard and soft tissue loss is still a current dilemma. Physiologically, the thin buccal bone plate is nourished by the periodontal ligaments (PDL) and the corresponding blood vessels, so the damage of the bundle bone-periodontal ligament complex (BB-PDL) is absolutely followed by marginal ridge contraction highlighted in the first 4 to 6 months after extraction, thus compromising the esthetics (Chappuis *et al.*, 2013)(Chappuis *et al.*, 2017), and therefore decreasing patient's satisfaction in any restorative intervention, especially in the anterior maxillary zone, knowing that the long-term esthetic outcome is being a major concern in combination to the efficiency in time and affordable cost treatment with increased benefit (Bäumer *et al.*, 2015).

In order to counteract this problem, many attempts have been made to introduce techniques that can preserve the alveolar bone and compensate for the occurring dimensional changes. Among these are interventions that preserve the extraction socket or apply ridge augmentation strategies (extract and augment approach) such as socket preservation methods, guided bone regeneration (GBR) by bone or bone substitute biomaterials with barrier membranes, ridge-split procedure, GBR with a bone block, in addition to soft tissue grafts (Mitsias *et al.*, 2017) (Gluckman *et al.*, 2016).

But even though these methods masked or limited the undesirable outcomes of alveolar bone loss, none of them have proven sufficient to eliminate the problem completely, as they have some limitations among which are high costs, issue of material availability, complexity and sensitivity of the procedure and so forth (Gluckman *et al.*, 2016). Thus, the pursuit for a standardized solution is ongoing. Following the same logic, partial extraction therapies (PET) were among the procedures invented to avoid volume diminishing of alveolar ridge by using the natural dental tissue itself (residual root or root fragment) (Gluckman *et al.*, 2016). Root submergence technique (RST), pontic shield technique (PST), and socket-shield technique (SST) are the PET interventions that made a turning point in reducing the consequences of post-extraction tissue alteration(Gluckman *et al.*, 2016) (Gluckman *et al.*, 2017).

2. MATERIALS AND METHODS

Thirteen years have passed since socket-shield technique, the most recent among those therapies, had been introduced to the spectrum of implant dentistry. Science behind, evidence of the technique, advantages and disadvantages, complications, technique modifications and long-term follow up are being introduced to the bulk of knowledge with time. The aim of this dissertation is to illustrate as clearly as possible, but also to evaluate, the utmost available information about socket-shield technique through a literature review.

All electronic searches included human clinical studies the following databases: PubMed-MEDLINE, Web of Science, and Google Scholar. Article researches were performed using the following terms: Partial extraction, post-extraction alveolar resorption, dental implants, Socket-shield, Root-membrane, Bone preservation, Root submersion.

Through a bibliographic search we have selected a total of 34 articles over 288 positive results. Arbitrary inclusion criteria were applied for the articles in this review, studies published between January 01, 1990, and February 2022, including human clinical randomized control trials, case-control studies, case series, studies including case reports investigating the socket-shield technique, and some explicative animal studies available in the English language;

Exclusion criteria were articles not related to the topic, articles in other language than English, literature reviews, articles before 1990. The included articles are published between January 1990 and February 2020. A descriptive and analytical study of the data is carried out to examines the available evidence regarding the partial extraction and especially the socket-shield technique.

2. SOCKET-SHIELD TECHNIQUE AND IMMEDIATE IMPLANT PLACEMENT

3.1. History:

The idea of placing implants in contact with functional PDL goes back to the 1990's, when Buser and colleagues made an attempt via animal trials to insert implants adjacent to PDL; that is, indirectly contacting the bone, to form the so-called "hybrid" implant and they failed (Mouraya *et al.*, 2018). However, they opened eyes extensively on a new finding: formation of a cementum layer colonized with collagen fibers over implant's surface in contact with the maintained root fragment (Buser *et al.*, 1990). With the passage of time, this observation was utilized by other researchers who applied the concept on ankylosed teeth and noted successful outcomes over a period of time ranging between 12-42 months (Davarpanah *et al.*, 2009). Simultaneously, a clinical study interested in the technical field of the method, described an innovative drilling protocol that uses surgical burs into remaining roots to initiate the bed for the implant aiming to extract atraumatically (Yalcin *et al.*, 2009). Histologically, Hürzeler and coworkers investigated the totality of the previous results via an animal study and ended up with a clear relation emphasizing that intentional buccal root fragment retention into a socket followed by immediate implant placement successfully maintains blood supply to the area and consequently prevents ridge collapse (Hürzeler *et al.*, 2010)

3.2. Science behind:

Based on the investigations of old studies, decoronation of ankylosed teeth is supposed to be a method of GBR since it leads to replacing retained tooth structure by bone tissue in a process done by osteoclasts and osteoblasts with time, thus maintaining bone dimensions (Hürzeler *et al.*, 2010). This observation helped developing the idea of retaining roots of teeth having normal periodontal space similar to ankylosed teeth and watching out the results as it is the case with RST (Hürzeler *et al.*, 2010). Accordingly, it was justified that keeping the supra-periosteal fibers healthy and supporting the peri-implant tissues will in turn maintain the triad formed of bundle bone-periodontal ligament-tooth from being disturbed and therefore, reducing overlying soft tissue contraction and the consequent esthetic alterations (Gluckman *et al.*, 2016) (Hürzeler *et al.*, 2010).

Furthermore, the protection of this natural periodontium enhanced the defense mechanism against bacterial accumulation knowing that it is considered the number one cause of periimplant failure (Sun *et al.*, 2020). In the proof-of-principle report; carried out by Hürzeler and colleagues, summing up the histologic results of the experiment held out on a beagle dog, the science behind socket-shield technique was proven where similar outcomes regarding hard and soft tissue preservation were illustrated in the presence of adjacent fixtures (Hürzeler *et al.*, 2010).

Additionally, the flapless characteristic of the SST procedure potentially supported the decrease of blood supply loss and added an advantageous trait (Sun *et al.*, 2020). A backscatter detector of a scanning electron microscope (B-SEM) and a light microscope (LM) were used to process the histologic fragments of the sectioned dog's premolars (P3 and P4) of the initial technique (Hürzeler *et al.*, 2010). Results showed evident root fragment attached buccally through natural PDL to the bone and an ossteointegrated implant, the two compartments were separated by a 0.5-mm gap occupied by connective tissue. Neither inflammation at the level of the junctional epithelium, nor resorption of the shield were detected, in addition to equal levels of bone buccally and lingually (Mitsias *et al.*, 2017) (Hürzeler *et al.*, 2010).

With the aid of increased magnifications, evidence of new cementum layer formation and disorganized mineral tissue construction between the implant threads and the shield was accomplished (Hürzeler *et al.*, 2010). This was also reported in a human histologic study done by Mitsias et al. after 5 years of implantation using RMT, where great quantities of compact bone surrounded the successfully ossteointegrated implant (Mitsias *et al.*, 2017).

3.3.Technique description and clinical aspects:

The socket-shield technique carries a variety of consecutive steps, from socket-shield preparation arriving to prosthetic management and follow-up. These steps may slightly vary as a result of progressive technique modifications. Note that the following procedure is described as pioneered by Gluckman et al. (Gluckman *et al.*, 2020).

Any tooth having a suitable indication for SST; that is adapting the requirements of the technique, can be designed to partial extraction and receive an immediate implant thereafter. After informing the patient about the detailed procedure via a consent form (Hürzeler *et al.*, 2010) and performing pre-operative scaling treatments for gingivitis (Bäumer *et al.*, 2017), a thorough clinical exam must be made to get a clear planning (Gluckman *et al.*, 2017). Three dimensional cone beam computed tomography (CBCT) images prior to the procedure is considered a must for applying the implant in an ideal 3D position as well as checking the status of the tooth for possible bone or root resorption, dehiscence or fenestrations, apical pathologies, and length and width of the target root. All this is to be completed by measurements related to antibioprophylaxis and adequate local anesthetic procedures (Gluckman *et al.*, 2017), in addition to the use of a 0.12% chlorhexidine mouthwash for 1 minute before the surgery begins (Bäumer *et al.*, 2017).

As a first step, tooth decoronation is held where the crown of the concerned tooth is cut off at the gingival level (Gluckman *et al.*, 2017) (Gluckman *et al.*, 2020), rather than being about 1mm below it as firstly described by Hürzeler et al. and precautions are taken in order not to harm the soft tissues. A post, if present, should be carefully removed using high-speed irrigated turbine with a suitable bur (Gluckman *et al.*, 2020). Secondly, canal system contents, whether root canal fillings or natural vascular and neurvous tissues are present, are to be cleaned using Gates Glidden number one. A peri-apical radiograph is recommended at the point to estimate root length (Gluckman *et al.*, 2020). Additional canal widening is required by Gates Glidden instuments with consecutively increasing sizes. Thereafter, a long-shank surgical bur is used through the root down to the apex to remove this latter (Gluckman *et al.*, 2020). For technical ease, the practitioner might use an intracanalar instrument through the root canal to make sure of his axis orientation (Gluckman *et al.*, 2017).

At this stage, periapical radiographs taken with a radiopaque instrument into the site play an essential role to rule out any injury or penetration to the adjacent bone and teeth, check the depth, and make sure the apex is removed (Gluckman *et al.*, 2017) (Gluckman *et al.*, 2020). The remnant root is further cut mesio-distally by a resection bur in a painting motion to create a curved arc along the total length (Gluckman *et al.*, 2020). In case of adjacent fixtures, extend the buccal shield to the mesial and distal sides in order to protect the interproximal bone (Gluckman *et al.*, 2020). Then, a microforceps is used to carry out the palatal fragment very carefully after dislodging it buccally by a microperiotome put into the palatal periodontal space (Gluckman *et al.*, 2017) (Gluckman *et al.*, 2020).

Neither the labial portion of the sectioned root nor the buccal crest and PDL should be touched. The immobilization of the root segment is mandatory for the maintenance of the corresponding periodontal apparatus; this can be verified by maintaining a finger rest which ensures tactility as the practitioner reaches the apical end. If a tactile sensation was felt, it indicates either that the buccal portion has moved while retrieving the palatal one, or incomplete root separation (Gluckman *et al.*, 2017) (Gluckman *et al.*, 2020).

The clinician must watch out carefully for any mobility of the buccal portion, this can be achieved by a probe applied to the inner surface of the segment. Once this is accomplished, the apex should be removed out along with any periapical infection and endodontic fillings by micro-curettes and extenssive saline irrigation (Gluckman *et al.*, 2017) (Gluckman *et al.*, 2020). Now, the portion is ready to be further prepared in order to play the designed role, namely the socket-shield. After making sure the gingiva is protected by a barrier the coronal part of the remaining buccal segment is to be reduced to the crestal bone level using a large diameter round bur (Gluckman *et al.*, 2020).

Consecutively, the segment must be reduced in thickness to approximately half it's orginal one as recommended by the authors who claim that this is an optimal thickness for imlplant accomodation in the left space (Gluckman *et al.*, 2017), and better forces distribution (Gluckman *et al.*, 2020).

This step must transform the fragment into a C-shaped concavity resembling the external alveolar bone concavity. Bäumer et al. (Bäumer *et al.,* 2017) (Bäumer *et al.,* 2017) in their retrospective case series, reduced the thickness of the shield to be about 2-3 mm. Prosthetically, Gluckman et al. (Gluckman *et al.*, 2020) ratify a coronal 2 mm-chamfer for better soft tissue growth.

Recently, Chen et al. introduced a digitally-fabricated titanium template by a computer-aided design and computer-aided manufacturing (CAD-CAM) system to optimize the results and facilitate the technical aspect of SST (Chen *et al.*, 2019). Briefly, the main advantage behind the template was to guide the practitioner throughout the procedure by decreasing the working time through preoperative planning using a prosthetically-driven surgical guide. Additionally, the pre-surgical estimation of the characteristics (length and thickness) of the shield was an added value (Chen *et al.*, 2019).

At this stage, double checking for mobility and saline rinsing once again is sanctioned. To ensure no perforations of adjacent structures were made, no sharp edges were kept, and complete root preparation was obtained, a periapical x-ray might be requested (Gluckman *et al.*, 2017)

(Gluckman *et al.*, 2020). The surgical protocol is shifted towards conventional complete extraction and immediate imlant placement in case of shield dislodgement and mobility during the procedure. Nevertheless, a thin bone plate or a fenestration does not orient the protocol towards an alternative (Bäumer *et al.,* 2017).

By this, the obtained shaped root segment occupying the buccal aspect of the coming implant's bed is the "socket-shield" (Gluckman *et al.*, 2020). The subsequent step is implant placement into the prepared site with the buccal portion in situ. It is inserted after necessary osteotomy towards the lingual aspect creating by that a buccal gap and avoiding shield dislodgement (Gluckman *et al.*, 2020). Regarding implant's spatial position in the socket, it is recommended to be 1.5 mm apical to the bony crest and around half a millimeter above the lower edge of the designed chamfer. Finally, application of grafting material to fill the gap between the implant and the shield is still debatable knowing that it is reasonable unless this gap is too tiny (Gluckman *et al.*, 2020).

Immediately loading the implanted fixture by a provisional restoration perfectly sealing the area is advocated by the original authors (Hürzeler *et al.*, 2010), under the condition that it is out of occlusion (non-functional loading) with the recommendation of soft food during the healing period as well as decreasing functional stresses over the implant site (Hürzeler *et al.*, 2010). The provisional prosthesis should allow a 2 mm-gap with the socket-shield so that soft tissue can fill the space (Gluckman *et al.*, 2017) and thus prevent shield exposure (Gluckman *et al.*, 2020). Comprehensive oral hygiene instructions in addition to necessary postoperative medications (antibiotics, pain killers, and chlorhexidine mouth rinses) are given to the patient and final prosthetic loading is restored after ossteointegration and healing (Bäumer *et al.,* 2017)

4. RESULTS

4.1 Results of animal studies:

Animal histologic studies accompanied the clinical ones, emphasizing that it is possible to get successful implant results on the ossteointegration and new bone formation levels (Hürzeler *et al.*, 2010). Electron and light microscopic results proved the ossteointegration of implants in the vicinity of root segments that did not show neither resorption nor inflammation in the proof-of-principle report of Hürzeler et al. (Hürzeler *et al.*, 2010). Adding to that, the appearance of a new layer of cementum in the socket-shield-implant interface (Hürzeler *et al.*, 2010).

In an animal histologic experiment, Zhang et al. studied the effects of SST on alveolar bone and soft tissues in four beagle dogs. Thirty-two extraction sites were included in the experiment classified into 4 groups, each group received either of the following procedures: blood clot solely, Bio-Oss Collagen product, SST plus blood clot, or SST with Bio-Oss Collagen. Quantitative and qualitative analysis of bone as well as volumetric updates using CBCT images and impressions taken at multiple time spots, respectively, revealed that the groups who were subjected to SST with either blood clot or xenograft had significantly better bone characteristics and lower width and height alterations (Zhang *et al.*, 2019).

In a pilot study in 2013, Bäumer et al. processed histologically specimens derived from three beagle dogs' maxillary jaws after proceeding through their 3rd and 4th premolars by SST with immediate implants. The results demonstrated that the labial plate was free of any resorption process, and bone was newly deposited in the gap between the fixture and the shield that was evidently surrounded by healthy PDL. In the same attempt, the authors executed a clinical test following the same procedure to a 69-year old female patient having a vertically fractured maxillary canine (Bäumer *et al.*, 2013). Digital superposition of scanned impressions revealed a 0.88 mm mean loss of hard tissue in the buccal sense.

4.2 Results of human trials:

4.2.1. Clinical results:

Siormpas et al. (Siormpas *et al.*, 2014) performed SST with immediate implant placement in the anterior zone extending from the canine to its contralateral in 46 patients. A 5-year follow-up period showed 100% implant survival rate with perfectly ossteointegrated implants. This retrospective study revealed stable alveolar bone levels with 0.18 ± 0.09 mm mesial and 0.21 ± 0.09 mm distal mean crestal bone resorption surrounding the implants according to the radiographic investigations (Siormpas *et al.*, 2014).

In 2017, Bäumer et al. (Bäumer *et al.*, 2017) also submitted 10 SST cases in a 5-male and 5-female sample. The study yielded well-healed fixtures free of peri-implant inflammations. Bone remodeling was physiological around the implants with a mean loss of 0.33 ± 0.43 mm and

0.17 ± 0.36 mm at the mesial and distal sides, respectively. Esthetically, a PES of 12 was scored, translated as a good esthetic outcome. With the aid of comparative superimposition of the digital 3D casts scans, volumetric analyses including those related to labial tissue contours were studied, and results were within normal ranges. In addition, the magnitude of gingival recession facing the implants was comparable to that of adjacent natural teeth (Bäumer *et al.*, 2017).

Simultaneously in 2017, a larger sample size subjected to immediate implant placement with intentional root fragment retention was held by Gluckman et al. (Gluckman *et al.*, 2018) . 70 males and 58 females were enrolled in the case series; it was the first study with a sample size beyond 100 cases at that time. In a medium period of follow up, the authors aimed to evaluate the survival rate of implants in a large sample, as well as the subsequent technique complications and their possible managements.

The survival rate scored 96.1% where 123 out of 128 implants survived. Precisely, among the total cases, 25 implants had complications (19.5%); five implants did not ossteointegrate and they got extracted, the remaining twenty had different complications among which are exposures (16 implants), infections (3 implants), and migration (1 implant) (Gluckman *et al.*, 2018). It is worth noting that no recessions (except for a 2-mm recession in a subject expressing internal exposure), no grey shadows indicating translucency of the implant, and no evidence of peri-implant infection were detected (Gluckman *et al.*, 2018).

In an attempt to weigh the socket-shield technique's efficacy in maintaining soft and hard tissue dimensional stability on the long run, Mourya et al. (Mouraya *et al.*, 2019) initiated a systematic review published in 2019, encompassing a variety of experiments and reports discussing SST from various aspects. At the level of human studies, the paper estimated that out of 489 implants placed using SST, 34 implants failed or had complications counting for 6.96%, a percentage pretty lesser than a previous review by Gharpure and Bhatavadekar (Gharpure *et al.*, 2017) who had 24.26% (33 out of 136 cases). Moreover, neither implant failures nor complications were detected for the animal studies in the review of Mourya et al. (Mouraya *et al.*, 2019), unlike Gharpure et al. (Gharpure *et al.*, 2017) who had 58 implant failures in 70 SST (82.86%).

This allowed the authors to conclude that with time, technique modifications, increased sample sizes, and long-term follow-up periods may allow SST promising outcomes, insisting that further evidence has to be established through RCTs to consider SST as a routine treatment (Mouraya *et al.*, 2019).

4.2.2. Histologic results:

Mitsias et al. implemented a human histologic study intending to add evidence-based knowledge about implants settled with SST in human anterior upper arch after five years of installation. The implant placed for a 68 year old patient showed, after retrieval, a successful ossteointegration with a high contact surface with bone (76.2%). No signs of volume diminishing of the buccal plate were observed, in addition to evident healthy PDL. Histologic and histomorphometric analysis indicated that the root membrane-implant interface was filled coronally with non-infiltrated connective tissue, whereas it was occupied by compact bone medially and apically (Mitsias *et al.*, 2017).

In order to histologically substantiate the arrangement of new bone and the ossteointegration between dentin tissue and an implant, Schwimer et al. engaged a case of a 45 year old woman who lost her implant due to peri-implantitis and was eventually removed. The results of the study revealed a root fragment having evident dentinal tubules covered by cementum near the implant which was covered by organized bone at the surface facing the root dentinal fragment (Schwimer *et al.*, 2018).

After this review of the accomplishments of authors who experimented SST, none had the absolute courage to report SST as a routine treatment option. It is common among the conclusions of recent articles that SST lacks randomized controlled trials and histologic evidence (Gluckman *et al.*, 2016) (Mouraya *et al.*, 2019) (Bramanti *et al.*, 2018).

5. ADVANTAGES AND DISADVANTAGES OF SOCKET-SHIELD TECHNIQUE

Socket-shield technique has added a group of pros to the world of implant dentistry. Preserving the blood irrigation network via the maintenance of the corresponding periodontal ligaments thus keeping minimal buccal plate resorption at implant site, was the main advantage of the novel therapy (Hürzeler *et al.*, 2010)(Siormpas *et al.*, 2014) (Han CH *et al.*, 2018).

In 2015, Gluckman and colleagues (Gluckman *et al.*, 2015) tabulated several advantages of SST along with some of its disadvantages. Fundamentally, it is evident that SST is less time consuming as it is a single operation requiring lesser surgical interventions which, in turn, decreases patient's painful and stressful feelings (Saeidi Pour *et al.*, 2017)(Gluckman *et al.*, 2015) (Calvo-Guirado *et al.*, 2016).

Moreover, the cost of additive materials is excluded, making the treatment more economic (Bäumer *et al.*, 2015)(Saeidi Pour *et al.*, 2017)(Gluckman *et al.*, 2015). Also, application of SST in sites having endodontic lesions in the apical area possibly exists (Gluckman *et al.*, 2015). Absence of co-morbidity increases the profit of the technique too as the second surgery site is not mandatory (Bäumer *et al.*, 2015) (Gluckman *et al.*, 2015) (Calvo-Guirado *et al.*, 2016). There is a possibility according to the literature that retaining roots can be exploited to sustain bone mass underneath removable dentures (Saeidi Pour *et al.*, 2017). SST is a good treatment option for patients with medical conditions that contraindicate other surgical interventions (Bäumer *et al.*, 2015).

This treatment modality is classified as minimally invasive according to Anas et al. (Anas *et al.*, 2017). The presence of the buccal fragment guiding the clinician during implant installation, makes SST superior to the conventional implantation protocol lacking the shield. Anas et al. (Anas *et al.*, 2017) also assume that SST preserves the tissues that allows structures surrounding the implant to be upheld.

Nevertheless, SST has the characteristic of being sensitive, it requires a detailed treatment plan written by an excellently trained operator as treatment's long-term success is highly skills-dependent (Saeidi Pour *et al.*, 2017)(Gluckman *et al.*, 2015). To highlight other disadvantages, one can write down the fact that SST owns short-term follow-up periods that yielded an impossible predictability of this procedure (Siormpas *et al.*, 2018) (Gluckman *et al.*, 2015).

Furthermore, the procedure of performing the buccal shield is considered complex since the operator has to unusually extract the palatal portion only, thus classifying the technique as practically difficult (Calvo-Guirado *et al.*, 2016).

6. DISCUSSION

6.1. Limitations of the socket-shield technique

It is of outstanding importance to point up the advantages of an innovative method in order to better understand its limitations. So, as previously described, SST showed great performance regarding esthetics and function (Bäumer *et al.,* 2015). But, it would be a remiss if one ignores the limitations of SST since this will absolutely end up in failures at different aspects whether technical, functional, or esthetical. Among the restrictions that were extracted from the literature come the following (Glocker *et al.*, 2014)(Gluckman *et al.*, 2016)(Anas *et al.*, 2017)(Gluckman *et al.*, 2017)(Nguyen *et al.*, 2020):

- Soft tissue injury during shield preparation by an unskilled clinician as the method is delicate
- Damage of the roots of neighboring teeth
- Fracture of facial bone plate during palatal fragment retrieval
- Periodontal or endodontic infections which threatens the success of the implant
- Failure to keep the root segment immobile throughout the process
- Small/thin and curved roots as for mandibular incisors and molar teeth, respectively
- Being sensitive, the technique requires accurate case selection where if absent, limits the successful outcomes
- Osteotomy drills may be injurious to the harmony between the buccal remnant fragment and the bone while shield preparation

Besides, what may temporarily limit the spread of the technique, is the fact that it is deprived of enough histologic evidence as samples are rare and of short-term follow-up (Mitsias *et al.*, 2017) (Gharpure *et al.*, 2017). Also, the procedure has surgical variants leading to slightly different designing criteria among recent studies. In addition, the conclusions concerning the results cannot be applied to humans directly as most of the published studies were undertaken on animals (Mitsias *et al.*, 2017).

As any other procedure, SST has some keys of success, it is worth noting that the omission of either of these keys might be a limitation of the technique.

6.2. Long-term follow-up

After it had been enormously popularized in the clinical field for only a decade, SST is still lacking long-term follow-up to better appraise its pros and cons. Going back to the literature, one can find a scarce number of long-term clinical studies which may be ignoring a lot of facts about socket-shield technique's clinical performance and future status (Siormpas *et al.*, 2018).

Till the meantime, the longest follow-up period goes back to Siormpas et al. (Siormpas *et al.*, 2018) who performed, retrospectively, a 10-year follow-up time with a mean of 49.94 months. 250 implants placed in the jaws of 182 patients from beginning of 2006 till end of 2016 were included in the study. The authors were pursuing to present a clear document about radiological data and clinical outcomes on the long run of deliberately designed shields since they considered that the complications collected by other reports were non-reliable as they watched out problems with implants near "accidently" retained dental segments. Siormpas and colleagues (Siormpas *et al.*, 2014) also, having the same purpose, published an earlier retrospective study (2014) with a shorter period of follow-up (5 years with a mean of 40 months). They tracked the outcomes of 46 patients subjected to RMT and immediate implantation (Siormpas *et al.*, 2014).

A more recent series of 3 cases was introduced in 2020 by Nguyen et al. (Nguyen *et al.*, 2020). They followed up their patients for a period ranging between 2 and 6 years and they achieved good results (Nguyen *et al.*, 2020).

During 2017, two five-year follow-up publications were implemented by Mitsias et al. (Mitsias *et al.*, 2017) and Bäumer et al. (Bäumer *et al.*, 2017). In the study of Mitsias et al. (Mitsias *et al.*, 2017), one patient was enrolled whose implant was retrieved for histology. Regarding the case series of Bäumer et al. (Bäumer *et al.*, 2017), 10 patients were followed up with a mean of 58 months. In 2018, a prospective cohort study demonstrated the cases of 15 patients and kept following them up to 5 years (Hinze *et al.*, 2018).

Three major factors bumped into the way of discovering the scientific reliability of SST and are common among the studies of current literature: the nature of the published study, the follow-up period of time, and the sample size (Siormpas *et al.*, 2018). A study is either prospective in nature, retrospective, or a randomized controlled trial. Taking one scenario, if a study is prospective or an RCT, it either lacks sufficient recall appointments on long run, has a small sample size, or both as it is the case with Han et al. (Han CH *et al.*, 2018) and Bramanti et al. (Bramanti *et al.*, 2018) who had both imperfections. To be clearer, Han et al. (Han CH *et al.*, 2018), who made a prospective study, recruited 30 patients with only a year of follow-up. Moreover, in the RCT of Bramanti et al. (Bramanti *et al.*, 2018), a 36-month follow-up for 40 patients only was reported.

On the contrary, 3 studies had the chance to show moderate-term follow-up and larger numbers of involved patients as with Mitsias et al. (Mitsias *et al.*, 2017), Siormpas et al. (Siormpas *et al.*, 2014), and Bäumer et al. (Bäumer *et al.*, 2017), but they are, in fact, retrospective. Another scenario was seen with Hinze et al. (Hinze *et al.*, 2018) who did well in following up the cases prospectively, but failed to accomplish the third factor related to sample size (only 15 patients).

A relatively acceptable follow-up time was registered by Gluckman et al. (Gluckman *et al.*, 2018) who looked after their 128 patients for 4 years. Mitsias et al. (Mitsias *et al.*, 2015) in their case study issued in 2015, adopted a 3-year follow-up plan for their patient. Abadzhiev and colleagues (Abadzhiev *et al.*, 2014) made a case-control study and followed a 2-year check-up protocol. A shorter time of supervision was chosen by Guo et al. (Guo *et al.*, 2018), who tracked the results for 18 months.

Very limited follow-up periods come with the case reports and series that form in fact the majority of the bulk of knowledge about SST, and they are considered untrustworthy to predict the long-term prognosis of SST (Siormpas *et al.*, 2018) (Gharpure *et al.*, 2017).

7. CONCLUSION

Currently, the most predominating knowledge in the literature concerning SST is the one derived from case reports and series which are, unfortunately, considered weak (Gharpure *et al.*, 2017). So, what about the future of SST? Is retaining root fragments fruitful on the long run? What is the fate of the residual segment? What is the long-term prognosis? Is grafting the buccal gap valuable? What type of tissues is generating in the gap? Could SST be an everyday standard? All these questions and many others are to be answered in the near future by histologic evidence and clinical attempts.

In conclusion, although it is evident that a great consensus about the clinical and esthetic success of SST has been earned, there is a greater unanimity among authors that the aforementioned technique still requires long-term clinical follow-up (Mouraya *et al.*, 2019) (Gharpure *et al.*, 2017) (Nguyen *et al.*, 2020). So, to better criticize the validity of the "promising" outcomes of SST, more rigorous results are to be derived from RCTs and 3D volumetric superposition of data with the aid of CBCT and scans through a meticulous treatment planning where comparing these esthetic and clinical features with those of conventional techniques makes conclusions in favor of either technique over the other (Han CH *et al.*, 2018) (Sun C *et al.*, 2020)

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