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SOCKET SHIELD TECHNIQUE VS CONVENTIONAL TECHNIQUE IN IMMEDIATE IMPLANTS IN THE ESTHETIC ZONE: A SYSTEMATIC REVIEW

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INDEX

LIST OF SYMBOLS AND ACRONYMS

- PL: Periodontal ligament
- IMT: Immediate implant technique
- CT: Conventional technique
- SST: socket shield technique
- PES: Pink esthetic score
- BI: Bleeding index
- PL: Plaque index
- PD: Pocket depth

ABSTRACT

- Objectives: Evaluate dimensional changes of the vestibular bone (vertical, horizontal, or both), as well as to study secondarily pink esthetic score (PES), periodontal health status using the Bleeding Index (BI), Plaque Index (PI), and Pocket depth (PD) and survival and success rate in socket shield technique (SST) compared to conventional technique (CT) in the esthetic area in immediate implant in postextraction sites
- Materials and Methods: Following the recommended methods for systematic reviews (PRISMA), an electronic search was conducted in the MEDLINE COMPLETE, Web of Science, Scopus and Embase databases to identify all relevant articles published up until November 2021 on SST and CT. The inclusion criteria involve studies on SST and CT, randomized control trial (RCT), pilot studies and observational studies (OS). Studies that will provide data related to dimensional changes to the buccal bone, soft tissues and post operatory problems. A minimum follow-up of 3 months. Minimum number of 10 patients. To assess the quality of the studies included in this review, the ROBINS-I tool was used for the OS and the RoB-2 for the RCT's.
- Results: Of 200 potentially eligible items, 12 complied with the inclusion criteria. There was significant difference between 2 techniques as the mean average of SST in horizontal and vertical bone loss was 0.18 and 0.33, respectively compared to CT, which was 0.63 and 0.95. The average PES of SST was 1.7 higher to CT. All the periodontal measurements were higher in CT compared to SST. The success rate of the both techniques was 99.5%.
- Discussion: Despite the results obtained from the study some limitations can be observed to reach firm conclusion. There are no studies with follow up superior to 3 years hence the conclusions are related to short or midterm studies. In addition, lack of homogenicy was observed in evaluation methods and surgical technique. Moreover, there is no specific evaluation criteria to evaluate success as the criteria used in this systematic review is same as used for standard implant.
- Conclusions: Socket shield technique has lower horizontal and vertical bone reabsorption in vestibular, higher pink esthetic score and same success rate comparted to conventional technique

KEY WORDS

- Dental implantation
- Dental implant
- Immediate implant
- Immediate dental implant loading
- Labial bone thickness
- Socket shield technique
- Esthetics
- Aesthetics
- Alveolar bone loss
- Bone reabsorption
- Partial extraction therapy
- Root maintenance technique
- PDL root maintenance

1. INTRODUCTION

1.1 Dental implant

1.1.1 History of dental implant

The first dental implant protocol was presented by Branemark et al. which included a two-stage procedure, separated by a period of osseointegration of six months, prior to the prosthetic loading of the implant (1). Furthermore, this period was established because of the belief that solely complete hard and soft tissue healing would guarantee a good osteointegration (2,3).

1.1.2 Definition

A dental implant is a metal post that replaces missing teeth; specifically, the root(s) of teeth, while the prosthetic restoration replaces the crown. However, it requires sufficient alveolar ridge bone volume (height and width) at the time of placement to provide primary implant stability (4,5).

1.1.3 Alveolar bone reabsorption

Alveolar bone is a tissue that goes through changes throughout the entire life (6). In delayed implant placement, the implant is inserted 3-6 months post extraction, after the healing and remodeling of the alveolar bone (7). This remodeling can lead to greater bone resorption, which can lead to an unfavorable position of the implant (6). Additionally, there are several studies performed to evaluate alveolar bone loss after an extraction (8–10). In a study by Schropp et al. the authors indicated that there is 50% of the reabsorption of the alveolar width 12 months after extraction (11).

The changes in the alveolar bone can be before and after tooth extraction. Prior can be due to periodontal disease, trauma, and periapical pathology and after due to traumatic extraction (11).

The alveolar bone loss is higher in the vestibular surface as the buccal bone is thin and this can cause a disparity in palatal and vestibular bone (12). As a result, this makes harder the maintenance of esthetics and emergence profile (13).

1.1.4 Techniques

In the last few years, lots of techniques have been introduced to avoid or reduce this bone reabsorption such as immediate implant placement, guided bone regeneration, flapless implant placement, palatally positioned implants, and platform switched implants. Moreover, these methods have shown alveolar bone preservation anyhow, none of them completely prevents it, as the bone loss is related to loss of periodontal ligament (PL) (14,15).

1.1.5 Role of periodontal ligament

PL plays a major role in the remodeling alveolar process as it gives vascularization to the radicular cement and lamina dura, forming “bundle bone”. After extraction and during the healing process we can observe important resorption of the buccal plate, which is formed mainly by bundle bone (12). Consequently, a complete reconstruction of the peri-implant soft and hard tissue remains a big challenge in implant dentistry (16).

1.2 Immediate implants (Conventional technique)

One of the main advantages of the immediate implant technique (IMT), also known as the conventional technique (CT) is to provide a high level of esthetics for the patients in a short time. With this technique, the extraction of the tooth and the placement of the implant are performed in the same procedure, which allows a better tridimensional position of the implant and maintains the architecture of the soft tissues. Nowadays, there is a rise in the number of patients requiring esthetics in the anterior area (12). In the past, there has been lots of research about osteointegration of the implant and it is known as one of the determining factors to evaluate the success of the implant (17)(18). Nevertheless, this criterion is not sufficient to fulfill the demands of patients and professionals requiring esthetics (19).

1.2.1 Definition

Immediate implant is defined as an implant placed after tooth extractions in the same surgical procedure. This technique was introduced due to alveolar bone reabsorption caused by delayed implant placement (20). In single implant

placement, it demonstrated a similar success rate compared to delayed implant. (21,22). In addition to esthetics, IMP reduces treatment time as it lowers the number of surgeries and visits to the dentist, lowers treatment cost, and lesser patient morbidity (23,24).

1.2.2 Immediate implant placement without graft

Prior to the implant placement, it is important to do a complete diagnosis of the receptor zone. There is a criterion that needs to be followed (25–27):

- The entire vestibular bone wall at the extraction site. A study by Bramanti et al. (26) mentioned a minimum of 2mm buccal bone thickness post-extraction. is the key element. Additionally, Hämmerle et al. (27) observed a thin buccal plate (< 1 mm) as the risk factor for mucosal recession.
- Thick gingival biotype (25,27)
- No acute infection at the socket (25,27)
- Sufficient volume (3-5 mm) of the remaining bone in the apical and palatal direction of the extraction site to allow a correct implant insertion with sufficient primary stability (25).

Generally, this technique is done without raising a flap to avoid gingival recessions and alveolar bone resorption. Furthermore, the tooth is extracted as atraumatically as possible (25–27).

1.2.3 Immediate implant placement with bone graft

In the majority of the cases, the criteria mentioned earlier is not accomplished. In these cases, instead of preserving, it can contribute to more vestibular bone reabsorption that can lead to an apical shift in the facial mucosal margin and alteration of facial contour causing poor esthetics (16,28). Moreover, clinically the thickness of the vestibular marginal bone in the anterior maxilla is <0.5 mm and <1 mm in 50% and 90% of cases, respectively (29).

Therefore, the techniques based on the biomaterial were introduced (29,30). The material is applied in the gap between the implant and vestibular bone which leads to clot formation which is subsequently followed by bone formation (31).

The biomaterials used nowadays are the following:

- Autograft (Bone is extracted from the same individual which increases new bone formation)
- Allograft (the bone extraction is from the same species but another individual)
- Xenografts (material of biologic origin but of different species)
- Alloplasts (synthetic origin material such as polymers, calcium phosphates and glass ceramics) were introduced (29,30).

What's more, other techniques such as immediate provisionalization (preserve soft tissue architecture and maintain natural emergence profile) and connective tissue grafts were also applied (28,32).

Despite all these techniques, the desired esthetical result can only be achieved in certain cases as the main problem is related to the extraction of the tooth (loss of PL and bundle bone) which causes bone reabsorption leading to the recession of peri-implant soft tissue (26,33).

1.3 Socket shield technique

After the inability of different techniques such as conventional technique, bone graft, and membrane to avoid buccal bone reabsorption in postextraction sites and remodeling of peri-implant soft and hard tissue, the root preservation technique was introduced. Considering the bone reabsorption is related to the loss of periodontal ligament, therefore it can be assumed that preserving PL in the buccal portion of the root avoids the physiological absorption of the buccal wall which is usually triggered by convectional tooth extraction. It can contribute to the preservation of vestibular bone and peri-implant soft tissue hence, improving esthetics (34). Even more than that, there have been studies that demonstrated that retaining roots cannot only preserve bone, it can even enhance vertical bone growth (35).

1.3.1 Definition

Socket shield technique (SST) is a technique in which a small labial coronal fragment of the root is maintained in place to preserve the blood supply

reaching the facial cortical plate from the periodontal ligament and an immediate implant is placed palatal to the root fragment (24,33,36,37). Besides, this technique “misleads” the bundle bone as the PL remains attached to the dentine and cement of the vestibular root fragment (38,39).

1.3.2 History

The preservation of decoronated roots in the alveolar process have studies that demonstrated that it not only helps maintain existing bone volume but also accelerate vertical bone growth, which can be observed coronally to the decoronated root (35,40).

The root submergence technique was used in the pontic side in implant therapy to avoid vestibular bone reabsorption. It consists of resecting the crown of the tooth, covering it with a buccal flap, and submerging the root. Moreover, this technique is used under complete dentures, pontic site for implants, and bone preservation for future implants (41)

1.3.3 The first studies in Socket Shield Technique

The first study using SST around implants was done in dogs by Hürzeler et al., 2010 and no vestibular reabsorption was observed. In addition, there was new bone formation. In this study, the methodology was not mentioned yet it was an important step towards the evolution of SST. This technique consists of beheading the crown with a diamond bur 1 mm apical to the gingival margin. Later on, the osteotomy drills are used to prepare the implant bed on the lingual portion of the tooth. Following osteotomy, residual root fragments on the lingual, mesial and distal walls are removed. The enamel matrix derivate is placed on the internal aspect of the root fragment. Finally, the implant is placed next to the buccal fragment (42).

The second study using SST in humans was reported by Siorpmos et al. in 2014. This technique is the same as the original but it was more detailed. The thickness of the remaining buccal root is 1 mm. After removing the residual fragments, the next step mentioned is separating the buccal root portion from the remaining root structure by a bur in mesial to distal direction. Moreover, enamel matrix derivate was not used in this study (43).

1.3.4 Variations of the technique

A continuation, Gluckman et al. proposed modification of SST technique, renamed partial extraction therapy. Additionally, this study suggested placing a graft between the remaining root and the implant. Socket shield is prepared at the level of crestal bone due to complications related to the supracrestal labial root. It also indicates the making of the chamfer in the crestal 2 mm of the buccal shield, thinning it slightly and giving extra and critical prosthetic space of 2–3 mm between the subgingival crown contour and the socket shield for soft tissue (44,45).

Furthermore, the implant bed is prepared after removing the palatal fragment as in the original technique it was prepared by going through the palatal root. The implant is placed further from the buccal fragment instead of next to the fragment (44,45).

In addition, other studies support the concept of not placing the graft in the gap as SST consists of preserving PL which provides necessary vascularization; Siormpas et al. and Mitsias et al. refer to this technique as root membrane (RM) (43,46).

Schwimer et al. in 2018, published the first human histology study which demonstrates the bone formation between dentin of the remaining root and the implant surface (47).

In the last 5 years, there was an increase in the number of studies indicating SST as an alternative to maintain marginal bone, peri-implant soft tissues, and implant stability (33,48,49). Even though this technique has lots of advantages, it is not 100% efficient as there are certain complications and challenges to overcome. Complications such as bone loss, a peri-implant infection can lead to implant failure (50).

1.3.5 Indication and contraindication

The SST is mainly indicated in the anterior areas because of esthetics (particularly anterior maxilla) even though, it can also be performed in the posterior region (37). Furthermore, it can be performed in cases where postextraction reabsorption is suspected to prevent the collapse of the vestibular bone (37,45). It can also be used in a patient with non-restorable teeth due to traumas (crown fractures) (39,45). Other indications are failed endodontic and

restorative treatments, destructive caries, and lack of ferrule (45). It is mainly indicated in the immediate implant (39).

SST is not indicated in the present (or past) periodontal disease (attachment loss >3 mm), or widening of the periodontal ligament, teeth with external/internal absorptions, vertical or horizontal root fractures below bone level (37) and mobility, extensive facial bone dehiscence (45)

There are relative contraindications such as deep residual periodontal bony defects, extensive apical pathology, and apicofacial bone fenestration (45). Afterward of the treatment of these defects, SST can be performed (47).

1.3.6 Advantages

The main advantage of SST is the maintenance of peri-implant soft tissues and an increase in gingival esthetics. It maintains pink and white esthetics in a patient with a high lip line. Further, the root fragment reduces vestibular bone reabsorption and recession of interproximal gingiva. In addition, it prevents the usage of bone graft hence the lower cost. It is more comfortable for the patient as it has fewer surgical procedures, less morbidity, and fewer visits to the dentist (51,52)

1.3.7 Complications and limitations

The main complication of SST is implant failure due to a lack of osteointegration. Another is an infection around the implant which can also lead to the removal of the implant. The most common complication is exposure (a coronal portion of the buccal shield piercing the soft tissue). It can be known as internal shield exposure and external shield exposure. Sometimes this complication can be treated by reducing the exposed fragment. The study by Gluckman et al. (44) indicated that these complications can be avoided by modifying the SST technique mentioned by Hutzler et al. (42).

SST is a sensitive technique that needs extensive planning and careful palatal fragment extraction. It requires accurate root fragment preparation and implant placement. It is complicated in the smaller root as seen in the curved root in molars and lower anterior tooth. The most important is to have an experienced dental team as this technique is more difficult and time-consuming. The full-

thickness flap is not recommended as it leads to bone reabsorption and soft tissue recession through at times it is necessary to have good vision (37,53,54).

1.3.8 Surgical technique for vital tooth

1.3.8.1 Preoperatory

The treatment and diagnostic are essential to avoid complications during and after surgery. The diagnosis is carried out radiographically by CBCT and clinically by intraoral exploration. Before surgery, if the patient manifests gingivitis, it is treated by prophylaxis and oral hygiene instructions (45).

1.3.8.2 Surgery

Following extra-oral disinfection of the surgical sites, the patient is asked to rinse their mouths with Chlorohexidine1.25% mouthwash. In continuation, local anesthesia is applied and the tooth is decoronated 1mm above the gingival level using a conventional chamfer diamond bur (45).

1.3.8.3 Root extraction

Afterward, the palatal/lingual segment is separated from the vestibular in a mesiodistal direction from the gingival margin till the apex of the tooth. The palatal segment is removed carefully to avoid dislodgement of the vestibular root segment. The labial fragment is trimmed at the bone crest and is carefully beveled towards the implant, such that the shield width is 2 mm and length greater than a third and less than a half of the root length. The internal beveled chamfer is created at the bone crest and socket shield is smoothened and all sharp areas are removed. It is important to verify the mobility of the vestibular fragment Residual tissue is eliminated with gentle curettage (33,45).

1.3.8.4 Osteotomy and Implant placement

In the next step, an osteotomy is prepared in palatal, further to the retained fragment by the different diameter of drills and subsequently, an implant is placed 1.5 mm below the alveolar crest and 0.5 mm above the apical limit of the chamfer. The gap can be o not be filled with biomaterial. In the end, a healing abutment or provisional crown is placed (45).

2. Justification, hypothesis and objectives

2.1. Justification

As explained previously, following tooth loss, there is a process of bone reabsorption, both vertically and horizontally. Bone absorption is a fairly common problem when it comes to tooth rehabilitation with implants or any type of fixed or removable prosthesis (7). SST is a technique introduced 10 years ago; however, it has evolved most in the last 5 years. Nevertheless, there are very few studies comparing the socket shield technique and conventional technique to determine and compare the outcome of these techniques. The relevance of this systematic review is to allow dentists to carry out this technique as routine in everyday practice safely taking into account all the risk factors and possible complications. For this reason, this systematic review was developed to evaluate the efficiency in terms of bone loss and esthetics of peri-implant soft tissue in SST compared to the conventional technique.

2.2. Hypothesis

The hypothesis of this study considers that SST will obtain better results compared to conventional techniques in vestibular bone loss, pink esthetic score, and peri-implant soft tissues in Immediate implant in postextraction sites.

2.3. Objectives

Primary objectives

- Evaluate dimensional changes of the vestibular bone (vertical, horizontal, or both) in socket shield technique compared to conventional technique in the esthetic area in immediate implant in postextraction sites.

Secondary objectives

- Evaluate the esthetics of the peri-implant soft tissues according to the Pink Esthetic Score and its health status using the Bleeding Index, Plaque Index, and Pocket depth.
- Analyze the survival and success rate of immediate implants with the conventional and the socket shield technique.

3. MATERIALS AND METHODS

The present systematic review was carried out according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)(55). The prisma checklist is explained in the Annex 2.

3.1. Selection criteria

3.1.1. Protocol and focus questions

The database Medline complete, Web Of Science, Cochrane (Library of the Cochrane Collaboration), and Scopus were used to search the indexed articles on patients requiring immediate implants using socket shield technique or conventional technique, published up to 30 December 2021, to answer the following question: In the patients with immediate implant in the esthetic zone (P), does the socket shield technique (I) improve clinical outcome in terms of dimensional changes in width and height of the vestibular bone, changes in the peri-implant soft tissue, pink esthetics score, survival and success rate (O) compared to conventional technique (C).

This study question was established according to an adaptation of the question structured PICO (Population, Intervention, Comparison, Outcomes). This approach is suitable for conducting qualitative systematic reviews in health interventions. The format of the question was established as follows:

- P (population): Patients that require dental implant placement following tooth extraction in the esthetic zone
- I (Intervention): immediate implant placement with socket shield technique
- C (Comparison): immediate implant placement without socket shield technique or conventional treatment
- (Outcomes): dimensional changes in width and height of the vestibular bone, changes in the peri-implant soft tissue, pink esthetics score, survival and success rate

3.1.2. Inclusion and exclusion criteria

Before starting the study, a series of inclusion and exclusion criteria were assigned according to the PICO protocol.

The inclusion criteria are the following:

- Population: Patients of both sexes over 18 years of age who need an immediate post-extraction implant in the esthetic zone and still present an intact buccal cortical plate.
- Intervention: Implant placement according to the socket shield technique.
- Comparison: Implant placement according to the conventional technique, fully removal of the root with or without bone graft
- Outcome: Studies that will provide data related to dimensional changes to the buccal bone as the main variable. Variable collected as secondary: esthetics using the pink esthetic score, soft tissue evaluation such as Periodontal depth, bleeding index and plaque index and survival and success rate of dental implants.
- Type of studies: A minimum follow-up of 3 months. Minimum number of 10 patients. Randomized controlled trials, pilot studies and observational studies (prospective and retrospective studies)

The exclusion criteria are the following:

- Population: Patients with systemic disease or any medication (chemotherapy and radiotherapy) that affect bone turnover, smokers, and drug abusers were excluded from the study
- Intervention: Patients with no cortical buccal plate, infection, and severe periodontal loss in the corresponding root were also excluded.
- Comparison: The studies not comparing both techniques, socket shield and conventional technique were excluded
- Outcome: The studies not evaluating vestibular bone reabsorption or pink esthetic score pre and post-surgery were excluded.
- Types of studies: Clinical case, Series of cases, Revision, systematic review, three-dimensional finite element analysis, non-randomized studies, more than 5 years, and studies on animals.

3.2. Source of information and database

The search was done in 4 databases mentioned earlier (Medline complete, web of science, Cochrane Library of the Cochrane Collaboration and Scopus) with keywords: ´dental implantation`, ´dental implant´, `immediate implant´, `immediate dental implant loading', 'labial bone thickness´, 'socket shield technique', 'esthetics', 'aesthetics', 'alveolar bone loss', 'bone reabsorption', 'partial extraction therapy', 'root maintenance technique', PDL root maintenance'

Database	Search (IN ALL FIELDS)	Filters	Date
Medline Complete	((MH "Immediate Dental Implant Loading") OR (MH "Dental Implantation") OR (MH "Dental Implants") OR immediate implant) AND ("socket shield technique" OR "root membrane technique" OR "partial extraction therapy" OR "PDL root maintenance") AND ((MH "Alveolar Bone Loss") OR (MH "Bone Resorption") OR (MH "Esthetics, Dental") OR labial bone thickness)	No filters were used during the database search.	November
Web of Science	(Immediate Dental Implant Loading OR Dental Implantation OR Dental Implants OR Immediate implant) AND ("socket shield technique" OR "root membrane technique" OR "partial extraction therapy" OR "PDL root maintenance") AND (Alveolar Bone Loss OR bone resorption OR esthetics dental OR labial bone thickness)	No filters were used.	November
Scopus	((“Immediate Dental Implant Loading” OR “Dental Implantation”	No filters were used.	November

	OR “Dental Implants” OR “Immediate Implant”) AND (“Socket shield technique” OR “Root membrane technique” OR “partial extraction therapy” OR “PDL root maintenance”) AND (“Alveolar Bone Loss” OR “Bone resorption” OR “Esthetics Dental” OR “labial bone thickness”))		
Embase	('immediate dental implant' OR 'dental implantation' OR 'immediate implant' OR 'dental implant') AND ('socket shield technique' OR 'root membrane technique' OR 'partial extraction therapy' OR 'pdl root maintenance') AND ('alveolar bone loss' OR 'bone resorption' OR 'esthetics dental' OR 'labial bone thickness')	No filters were used.	November

3.2.1. Search in journals

The search was completed with a review of the references provided in each one of the studies to identify any additional studies than the initial search. Posteriorly, a manual search was done in scientific journals related to implantology and oral surgery; *Journal of Dental Research, Journal of Dentistry, Clinical Oral Implants Research, Clinical Implant Dentistry and Related Research, Journal of Oral Implantology, Alexandria dental journal, Implant Dentistry and Journal of Indian Society of Periodontology.* The duplicated studies were eliminated.

3.3. Data selection process

A three-stage selection process was carried out. The selection of studies was carried out by 1 reviewer (KKS). Once the duplicated between the two

databases had been eliminated, two screening were preformed to determine the eligibility of the studies. In the first screening, relevant articles were selected based on title and abstract. Irrelevant articles were then excluded based on the exclusion criteria. The second screening, consisted of reading the full texts of the articles included in the first screening phase. Articles were then excluded if they do not fit the inclusion criteria. The remaining articles were therefore the total number of articles included after performing a cross-search. Each phase was reviewed by the second reviewer (EW).

3.4. Data collection process

The following information was extracted from the studies for socket shield technique and conventional technique and set out in a excel document: First author, author's email, title of study, Journal, year of publication, type of study, language, country of study, trail registered and ethically approved, objectives of the study, number of patients (start and finish), gender of patients, diagnosis, sampling method, number of implants, location of implants, type of teeth, inclusion y exclusion criteria, stages of surgery, characteristics of the prosthetic restoration (type of provisional and definitive restoration), for conventional and SST **[**surgical technique, with or without bone graft, vestibular cortical bone loss (horizontal, vertical or both in mm), Esthetics (Pink esthetic score), Soft tissue (bleeding index, plaque index and sulcus dept, soft tissue recession), complications, follow up**]**, outcome, comparison of variable for socket shield and conventional technique, data analysis, conclusion, limitations and recommendation.

Principal variable

- Marginal vestibular bone loss: the amount of vestibular bone loss in horizontal, vertical, or both after immediate implants and comparison between conventional and socket shield techniques. It is measured using CBCT, OPG, and periapical x-ray in mm with a minimum of 4 months of follow-up after implant placement.

Secondary variable

- Survival and success rate of immediate implant: it is evaluated with the number of implant failures with at least 3 months of follow-up after implant placement.
- Esthetics: It is determined using the pink esthetic score (PES) score introduced by Furhauser et.al with a minimum of 4 months of follow-up after implant placement. Seven parameters were assessed compared to a natural reference tooth including mesial papilla, distal papilla, soft tissue level, soft tissue contour, alveolar process deficiency, soft tissue color, and texture. Using a 0-1-2 scoring system, 0 being the lowest, 2 being the highest value for each parameter. The maximum achievable PES is 14(56). In one article, PES is assessed by 5 parameters. It is a modification of the PES score mentioned earlier. The parameters for assessment are mesial papilla, distal papilla, the curvature of the facial mucosa, level of the facial mucosa, and root convexity at the buccal aspect of the implant site (57).
- Peri-implant soft tissue: probing depth (PD), bleeding index (BI), and plaque index (PI) are measured by a periodontal probe and filled in a periodontogram with a minimum of 7 months of follow-up.
- Complications: The complications appeared post-implant placement. It is evaluated with clinical examination and radiographs (internal shield exposure, external shield exposure, apical reabsorption).

3.5. Study Risk of Bias assessment

To assess the quality of the studies included in this review, the ROBINS-I (The Risk of Bias in Non-Randomized Studies (58)) tool was used for the observational studies and the RoB-2 (Cochrane Method Bias) tool for the randomized clinical trials (59). Bias related to the cofounding, participants, interventions, deviations from treated interventions, missing data, outcomes and report was assessed by the first reviewer (K.K.) and verified by the second reviewer (E.L.W.). Each of these domains presents its own risk of bias, in the final analysis an overall risk of bias was assessed for each article.

3.6. Data synthesis

In order to summarize and compare studies, values of the variables were grouped into each study group and then analyzed using the weighted average. The average was done by the sum of bone loss or pink esthetic score or periodontal measurements for each study divided by number of studies. The success rate was determined by success percentage in each article divided by number of articles.

4. RESULTS

4.1. Study selection

A total of 200 articles were obtained from the initial search process: Medline complete (n=30), Web of Science (n=51), Scopus (n= 100) and Embase (n=19. Of these publications, 10 were identified as potentially eligible articles after screening by titles and abstracts. The full text articles were subsequently obtained and thoroughly evaluated and 1 study was excluded. In addition, 3 studies were found through manual search (Journals and cross search). As a result, 12 articles met the inclusion criteria and were included in this systematic review (Fig 1).

The information related to exclusion of articles y reason for exclusion is presented in Table 1.

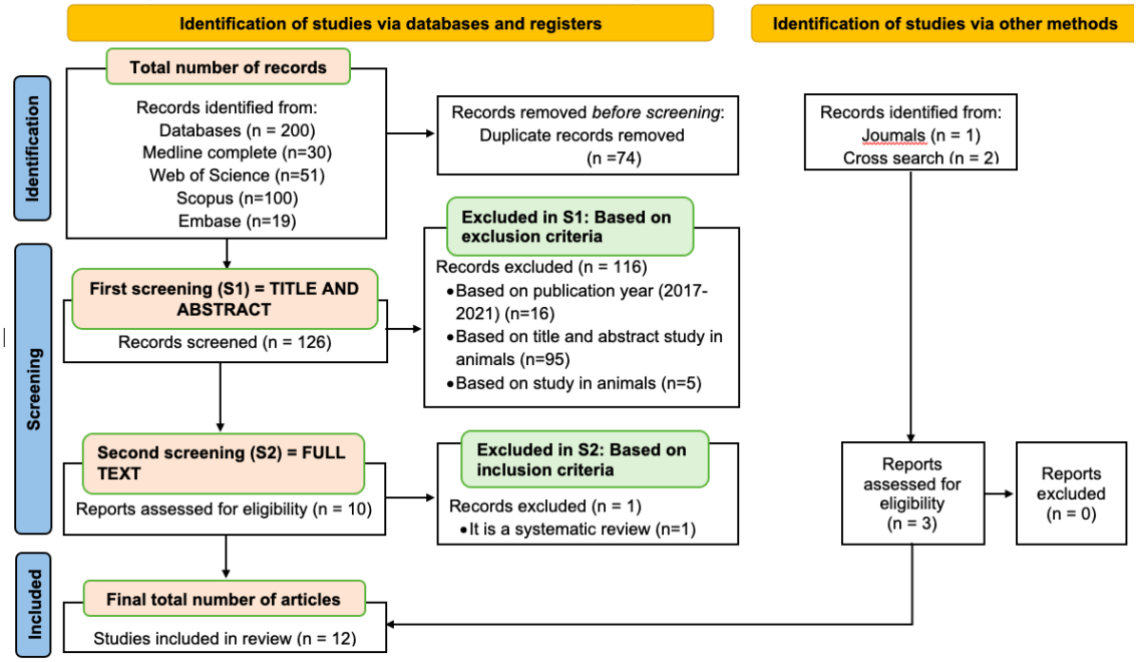

Fig.1. PRISMA 2020 flow diagram for searches of databases, registers and other sources for systematic revision.

Table 1. Exclusion of articles (and reason for exclusion) of this systematic revision.

Author and year	Journal	Reason for exclusion
Atieh et al.,2021(60)	Journal of esthetic and restorative dentistry	Systematic review

4.2. Study characteristics

As demonstrated in the table 2, 12 studies were included in this systematic revision (15,16,26,28,29,52,61–66). 7 studies were randomized controlled comparative clinical study (15,16,26,28,29,52,64,66), 1 prospective non randomized clinical trial (65), 1 retrospective comparative study (63), 1 prospective comparative study (62), and 1 a pilot study (61). All the studies compared conventional and SST technique. In total of 387 patients were included in the study. 178 patients received SST and 180 patients received implants by conventional technique. Moreover, 9 patients received both SST and conventional technique. However, in 20 patients, it doesn`t specify the technique. In total of 412 implants were placed; 206 as SST technique and other half as the conventional technique. Characteristics of articles included are described in table 2. Majority of the studies were done in maxillary anterior teeth and in adults over 18 years old, excluding 1 study with patients over 25 years.

Marginal bone loss was measured in 11 studies (15,16,26,28,29,52,61,62,64–66). Of these studies, 4 measured vertical and horizontal bone loss (15,16,28,66), 2 measured vertical bone loss (26,62) and 5 measured horizontal bone loss (29,52,61,64,65). More than half of the studies used CBCT to measure marginal bone loss and the remaining used periapical x-ray. Moreover, 10 studies measured PES (15,16,26,28,29,61–65). However, only 2 studies measured periodontal index such as bleeding index and periodontal depth (16,66). Besides, 1 study measured plaque index too (16). If there were any complications observed, they were too described in all the studies. Additionally, 4 studies also measured subjective scale, in which 3 measured patient's satisfaction about esthetics (28,64,65) and 1 study measured pain and esthetics (29). The patient's satisfaction about esthetics was measured by VAS in 3 studies (28,29,65) and by a ruler in the remaining study (64). Furthermore, the pain analogue was measured by VAS. In some studies, there were different follow up for each variable. Such as, 4 studies followed bone loss (15,16,28,29) for 6 months, from which 2 measured soft tissue for 12 months (16,28) and 24 months (16), respectively. 5 studies followed up for 12 months (52,62–65) and 1

for 36 months (26). In addition, 1 study had a follow up for 4 months (61) and the remaining 1 for 7 months (66).

Table 2. Characteristics of articles included in systematic review.

Author and year	Type of study	(participants/ implants)	Location and teeth	Age and sex	Variable measured (method assessment)	Follow-up
Atef et al.,2021(27)	Prospective randomized parallel two-arm controlled clinical trial	Total: (42/42) SST: (21/21) CT: (21/21)	Upper I and C Premolars	Artículo I. 6 ± 5.55 10 Males 30 Females	Horizontal and vertical bone loss (CBCT), Soft tissue (PES) Patient satisfaction (VAS), Complications	Bone loss: 6 months PES, VAS and complications:12 months
Abd-elrahman et al.,2020(15)	Randomized control clinical trial	Total: (25/40) SST: (-/20) CT: (-/20)	Maxillary anterior teeth	30.9 ± 5.5 11 Males 14 Females	Horizontal and vertical bone loss (CBCT) Soft tissue (PES) Implant stability (RFA), Complications	6 months
Bramanti et al., 2018(25)	Randomized control clinical trial	Total: (40/40) SST: (20/20) CT: (20/20)	Anterior maxillary and mandibular teeth	-	Marginal (vertical) bone loss (Periapical) Soft tissue (PES) Implant stability (ostell), Complications	3,6,36 months
Tiwari et al., 2019(52)	Randomized control clinical trial	Total: (16/16) SST: (8/8) CT: (8/18)	Maxillary anterior teeth	Mean age 24	Horizontal bone loss (CBCT)	1,4,8 and 12 months
Kumar et al., 2021(61)	A Pilot study	Total: (20/30) SST: (-/15) CT: (-/15)	Maxillary anterior teeth	Mean age 37 14 Males 6 Females	Marginal bone loss horizontal (periapical), Soft tissue (PES)	15 days and 4 months
Barakat et al., 2017(66)	Randomized Controlled Clinical Trial	Total: (20/20) SST: (10/10) CT: (10/10)	Maxilla SST: 6 I and 4 C CT: 7 I and 3 C	Mean age 35 8 Males 12 Females	Horizontal and vertical bone loss (CBCT) Soft tissue (PD, BI) Implant stability (ostell) Complications	4 and 7 months
Sun et al.,2019(28)	Randomized controlled clinical trial	Total: (30/30) SST: (15/15) CT: (15/15)	Anterior teeth	>25 years 7 Males 23 Females	Horizontal and vertical bone loss (CBCT) Soft tissue (PES, PD, BI, PI, Recession) Implant stability (RFA) Complications	Bone loss (6 months) Soft tissue (6,12,24)

Santhanakrishnan et al., 2021(29)	Randomized controlled clinical trial	Total: (150/150) SST: (50/50) CT: (50/50) DIP: (50/50)	Maxillary anterior teeth	30.1±8 34 Males 41 females	Horizontal bone loss (CBCT) Soft tissue (PES) Patient satisfaction (esthetics and pain analogue): VAS, Complications	6 months
Hana et al., 2020 (63)	Retrospective comparative study	Total: (40/40) SST: (20/20) CT: (20/20)	Maxillary anterior teeth	Mean age 51 26 Males 14 Females	Soft tissue (PES) Complications	12 months
Fattouh et al., 2018 (62)	Prospective comparative study	Total: (20/20) SST: (10/10) CT: (10/10)	Maxillary anterior teeth	>18 years old 8 Males 12 Females	Vertical bone loss (Periapical) Soft tissue (PES) Complications	Complications: 1 week, 4 week, 3,6,12 months. Other: 3,6,12 months
Zhang et al., 2020(64)	Prospective, double blind randomized controlled clinical study	Total: (60/60) SST: (30/30) CT: (30/30)	Maxilla 38 CI 22 LI	37.0+3.7 33 Males 7 Females	Horizontal bone loss (CBCT) Soft tissue (PES) Complications Patient satisfaction: esthetics (Ruler)	12 months
Xu et al., 2019 (65)	Prospective non Randomized clinical trial	Total: (24/24) SST: (12/12) CT: (12/12)	Maxilla 20 CI 4 LI	38.08+10.5 12 Males 12 Females	Horizontal bone loss (CBCT) Soft tissue (PES) Complications Patient satisfaction: esthetics (VAS)	12 Months

SST: socket shield technique, CT: conventional technique, I: Incisors, C: canines, CBCT: (Cone-beam computed tomography) systems, PES: Pink esthetic score, VAS: Visual analogue scale, RFA: Resonance Frequency analysis, PD: Periodontal depth, BI: Bleeding Index, PI: Plaque index, DIP: Differed immediate implant

4.3. Risk of bias

The risk-of-bias for randomized clinical trials (RCT) study included in the present systematic review was assessed using the Cochrane Collaboration tool RoB2 and for observational studies RoB1. Answering specific signaling questions permits one to determine domain-level judgments about the risk of bias. An overall risk-of-bias judgement of each study independently as well as an overall risk-of bias judgment across all included studies as a whole can be assessed based on the domain-level judgments.

4.3.1. RCT's

Illustrated in Fig. 2 is the overall risk-of-bias assessment of each study and Fig 3 as each domain across RCT studies. The first domain assessed was the risk of bias arising from the randomization process. This judgment depended on whether the allocation sequence was random and concealed. What's more it was crucial to note whether the results obtained suggested any problems with randomization. 7 (15,16,26,28,29,52,64) out of the 8 included studies included demonstrated a low risk of bias in this domain since the allocation sequence was random, concealed and the results did not suggested problems with randomization. The remaining 1 study (66) demonstrated some concerns in this domain since the studies did not mention information related to the randomization process. The randomization technique used in the studies included varied from, stratified block randomization (15) and computer-generated randomization (16,26,28,29). In the continuation, the second domain assessed was the risk of bias due to deviations from the intended interventions. The signaling questions pertaining to this domain reflect patient blinding, operator blinding and whether failing to do so had affected the outcome of the study. In all included studies, 6 studies (15,26,28,52,64,66) demonstrated some concerns as there was no specific information in the articles.

The third domain was risk of bias due to adhering to intervention and 6 studies demonstrated some concerns (26,28,29,52,64,66). The fourth domain assessed was the risk-of-bias judgment due to missing outcome data. This domain explores whether there was any missing information that may affect the outcome of the study. All of the studies included had a low risk of bias, when it came to this domain as all the studies included how many participants were included initially and at the end of the experiment. The fifth domain assessed was the risk of bias in the measurement of the outcome. The signaling questions pertaining to this domain explored whether the methodology to measure the variables were appropriate or not, examiner blinding, and the influence these factors had with the results obtained. All the studies included used the appropriate measuring methodology. The majority of the studies mentioned examiner blinding except for 2 (15,66). The examiner knowing, which participant received what intervention can influence the outcome of the results. Therefore, rest of the

studies demonstrated a low risk of bias for this domain. The last domain assessed was the risk of bias in the selection of the reported results. The signaling questions for this domain revolves around the consistency of what was planned to the assessed at the beginning of the trial and what was decided to be assessed afterwards. It also takes into consideration whether the numerical values being examined have multiple eligible outcome measurements and analyses of the data. All the studies included produced results in accordance with the analysis plane prior to the start of the trial. All studies measured the variables at multiple times, that is at baseline and many months afterwards. All studies demonstrated a low risk of bias. The overall risk-of-bias judgment for each study included in the present systematic review was low in 1 study (16), some concern in 5 studies (26,28,29,52,64) and high in 2 studies (15,66).

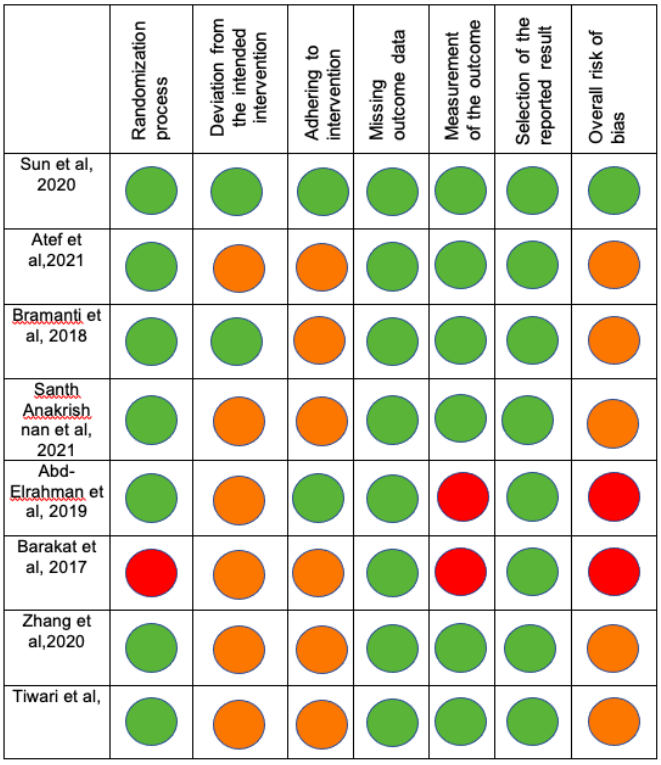

Fig 2. Assessment risk of bias of the included RCT presented with low (green), some concerns (orange), and high (red) risk of bias

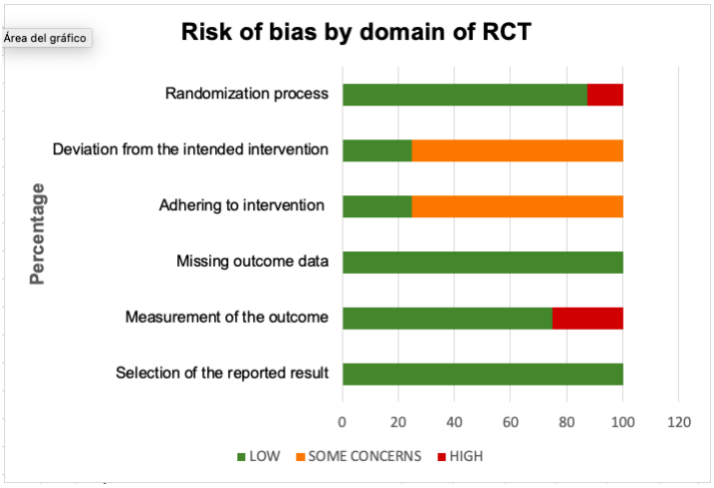

Fig 3. Assessment risk of bias by domain of the included RCT presented with low (green), some concerns (orange), and high (red) risk of bias

4.3.2. Observational studies

As regards to observational studies illustrated in figure 4 and 5, the first domain assessed was the risk of bias due to cofounding. 3 studies demonstrated moderate risk of bias (61–63) except 1 study (65) which showed low risk of bias.

The second domain assessed is the selection of participants. All the studies demonstrated low risk of bias as all participants who would have been eligible for the target trial were included in the study; and for each participant, start of follow up and start of intervention coincided. The third domain is classification of intervention. All the studies demonstrated moderate risk of bias. The fourth domain of risk of bias is deviation from intended interventions. All the studies presented low risk of bias as there were no systematic difference in both control and test group. Additionally, fifth domain of risk bias due to missing date demonstrated low risk of bias in all the studies as no data related to study was missing. The sixth domain of risk of bias was measurement of outcome. All the studies demonstrated moderate risk of bias due to outcome assessors may be aware of the interventions being received by each participant as there is no active blinding by the study investigators. This can influence the final outcome of the study as assessors can be biased to one type of intervention.

The final domain selection of the reported results, all the studies demonstrated low risk of bias as all the outcomes are defined in the same was in the materials and methods and results. The overall risk-of-bias judgment for each study included in the present systematic review was moderate in all the studies.

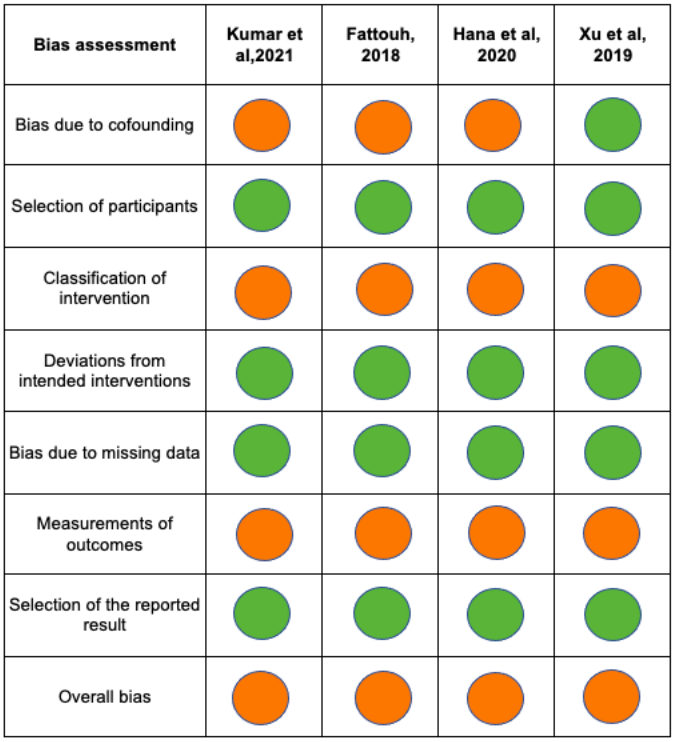

Fig 4. Assessment risk of bias of the included observational studies presented with low (green), moderate (orange), and high (red) risk

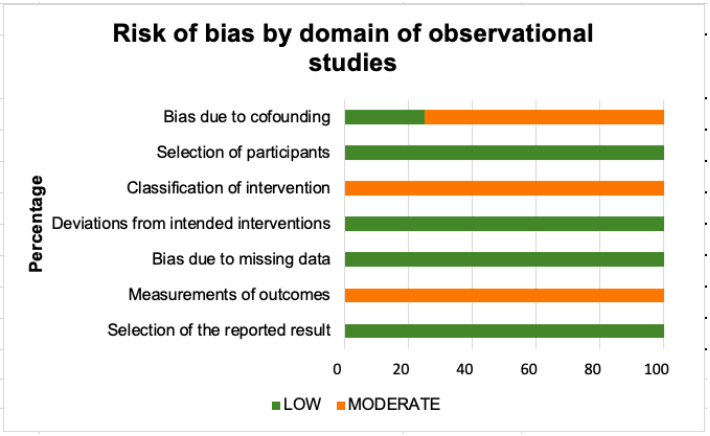

Fig 5. Assessment risk of bias by domain of the included observational studies presented with low (green), unclear (orange), and high (red) risk of bias

4.4. Marginal bone loss

The degree of reabsorption and changes in horizontal and vertical labial bone thickness is observed in figure 6 and 7, respectively and annex 3. The number of implants for sample for SST and CI were 213 and 213, respectively. Majority of studies followed-up for 6 months for SST and CT (15,16,28,29). However, there was a study with a follow up for 36 months (26) and even 1 for 4 months (61). 4 studies compared both horizontal and vertical bone changes (15,16,28,66). Furthermore, 5 (29,52,61,64,65) and 2 studies (26,62) compared horizontal and vertical bone changes, respectively. Therefore, 9 (15,16,28,29,52,61,64–66) and 6 studies (15,16,26,28,62,66) were included in horizontal and vertical bone loss, respectively. The radiographs for bone measurements for each study are mentioned in annex 4.

In respect to horizontal and vertical bone loss, all the studies demonstrated greater bone loss in CT compared to SST. The bone reabsorption of two techniques was between 0.03 to 1.71. There was significant difference between 2 techniques as the mean average of SST in horizontal and vertical bone loss was 0.18 and 0.33, respectively compared to CT, which is 0.63 and 0.95. Therefore, the differential average between 2 technique was significant as CT demonstrated additional 0.45 and 0.62 bone reabsorption in vertical and horizontal, respectively. In addition, the study by Atef el al. indicated the highest vertical 1.71 and horizontal bone reabsorption 1.42 in CT. It is 1.35 and 1.16 higher to SST, respectively. The study by Abd-alrahman el al. (15) reported the horizontal bone loss of 0.28 mm and 0.12 mm for the control and study group while the range of the vertical bone loss was 0.77 mm and 0.34, respectively. Regarding horizontal bone loss, Kumar el al. (61), demonstrated the highest bone reabsorption 0.73 by using SST. On the contrary, a study of Bramanti et el. displayed the lowest difference of 0.03 in vertical bone loss respectively compared to SST (28). There was significant difference between horizontal and vertical bone loss. As for CT, 4 studies in horizontal (28,61,64,65) and 3 in vertical (16,28,66), demonstrated higher bone loss than 0.8. Considering SST, no studies demonstrated bone loss higher than 0.8 in horizontal and vertical bone. In SST, regarding horizontal bone loss and vertical bone loss, 1 (61) and 1 study (66) showed reabsorption higher than 0.4, respectively. If compared to CT,

4 (15,29,52,66) and 1 study (26) had bone reabsorption lower than 0.4 in horizontal and vertical bone, respectively.

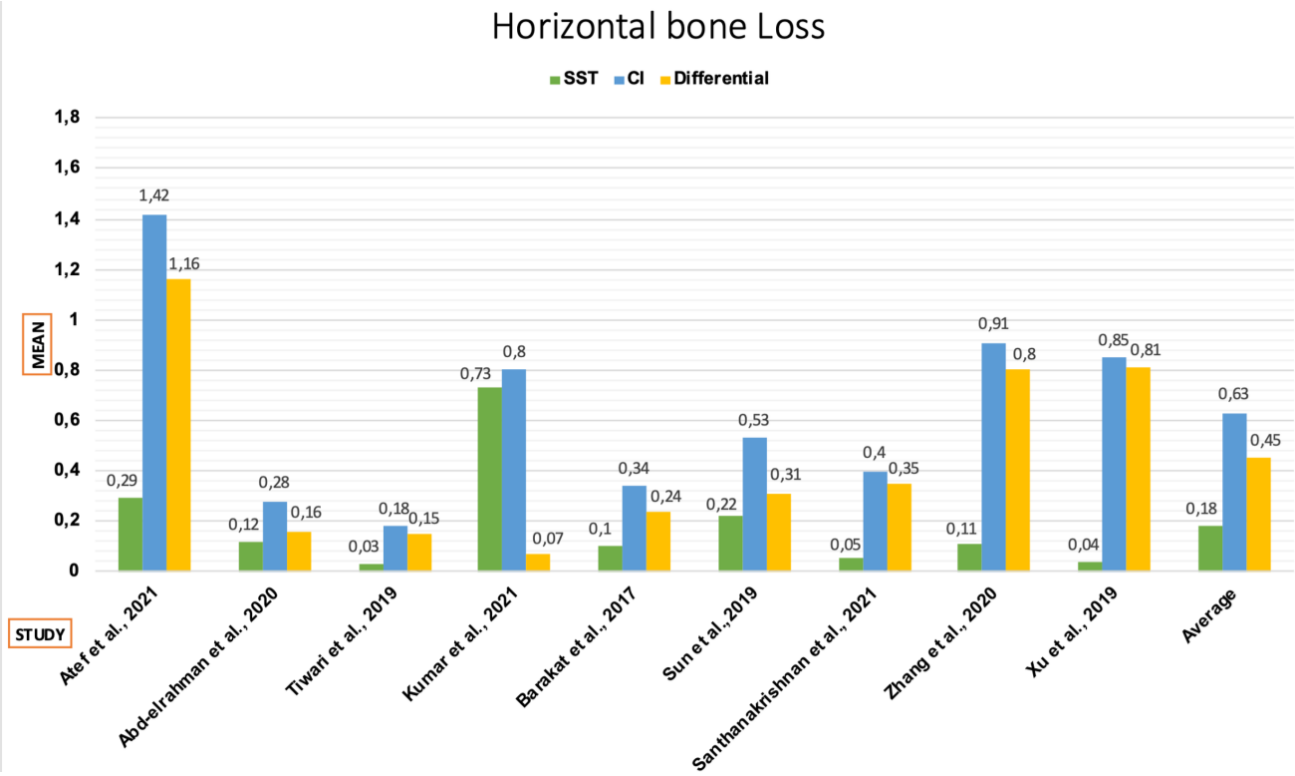

***Figure 6**. Immediate implant placement with socket shield technique versus conventional technique. Degree of reabsorption: Changes in width (horizontal bone loss) of buccal bone plate*. (SST: socket shield technique, CI: conventional technique)

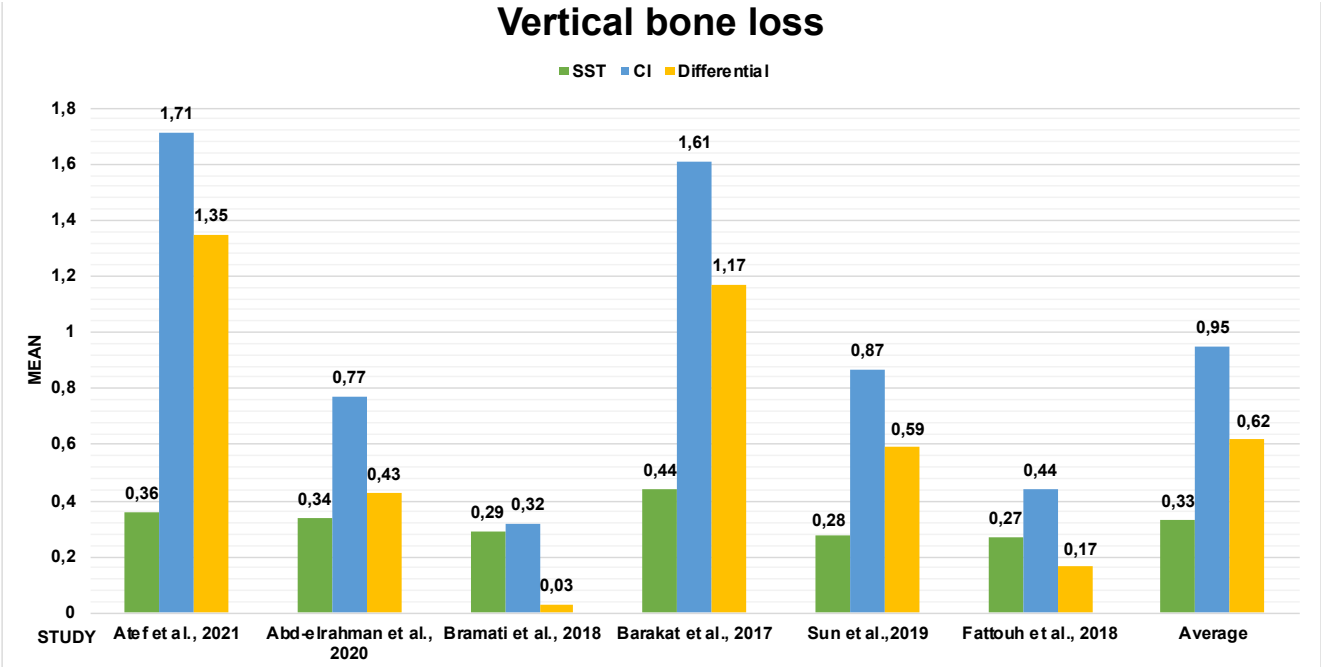

***Figure 7**. Immediate implant placement with socket shield technique versus conventional technique. Degree of reabsorption: Changes in height (vertical bone loss) of buccal bone plate*. (SST: socket shield technique, CI: conventional technique)

4.5. Pink esthetic score and periodontal index

In relation to esthetics as explained in figure 8 and annex 5, 10 studies provided data on pink esthetic score (15,16,26,28,29,61–65). The higher PES score indicates higher esthetics. The number of implants for sample for SST and CI were 213 and 213, respectively. We calculated the PES change in PES score before or immediately after surgery and at the end point of follow up from each article. The majority of the studies followed-up for 12 months for SST and CT (28,62–65). In addition, 2 studies had a follow-up for 6 months (15,29), 1 study for 36 months (26) and remaining 1 study for 24 months (16).

In respect to SST, 8 studies had PES score higher than 12 (15,16,26,28,61,63–65), whereas comparted to CT, where no score was above 12. Concerning SST, the highest score was 13,32 in the study by Zhang et al. (64). However, the highest score for CT was 11.86 by Atef et al. (28). As for the data extracted from the studies, the average of PES of SST was 12,3 compared to CT, whose average is 10.6. Therefore, the average PES of SST was 1.7 higher compared to CT. Regarding CT, study done by Abd-elrahman el al. (15) and Kumar et al. (61) were the studies that demonstrated PES score 3 points compared to SST.

All the studies using SST had higher PES score compared to CT. There was significative difference in PES score between 2 techniques in 6 studies, indicating CT PES score difference of more than 1 compared to SST (15,26,61,63–65). However, 4 studies demonstrated no significate difference as the difference between the 2 techniques was less than 1 (16,28,29,62).

In respect to periodontal measurement in table 3; bleeding index, plaque index and periodontal depth were measured. The study by Sun et al. indicated the difference of periodontal measurement from 12th to 24th months regrading SST and CT. Considering PD in study by Barakat et al. (66), the measurement was 1.73 in SST compared to 2.12 in CT. The periodontal difference between 12 months was 0.01 and 0.1 in SST and CT, respectively (16). All the periodontal measurements in all the articles, were higher in CT compared to SST.

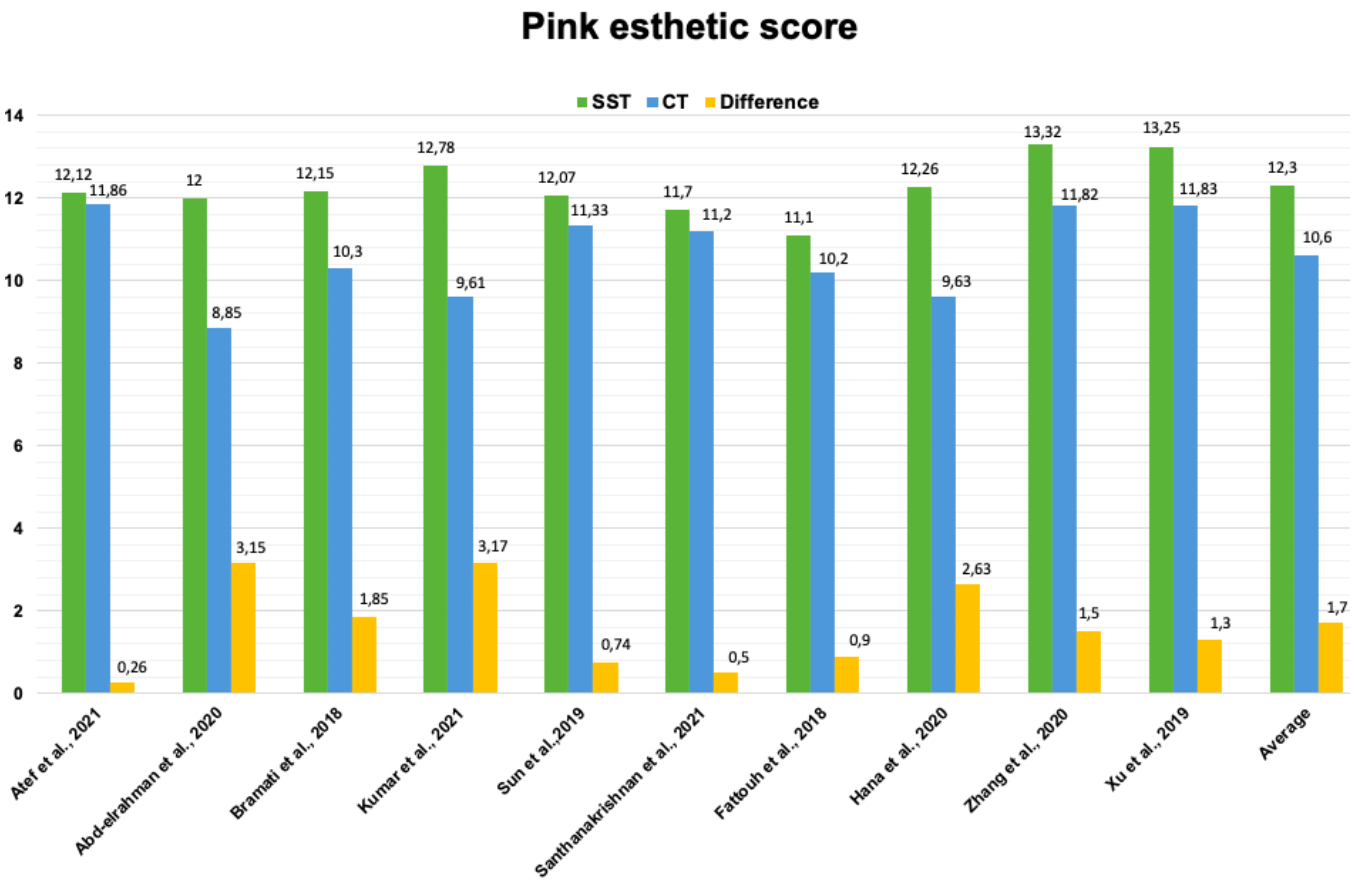

Figure 8. *Immediate implant placement with socket shield technique versus conventional technique. Changes in Pink esthetic score. (SST: socket shield technique, CI: conventional technique)*

Table 3. Immediate implant placement with socket shield technique versus conventional technique. Changes in periodontal measurement.

	Barakat et al., 2017				Sun et al.,2019			
	SST	CT			SST	CI		
	Mean	Mean	Dif	TI	Mean	Mean	Dif	TI
BI	0	0		10	0.01	0.03	0.02	15
PD	1.73	2.12	0.39		0.01	0.1	0.9	
PI	-	-			0.01	0.06	0.05	

(SST: socket shield technique, CT: conventional technique, Dif: difference, TI: total implants PD: Periodontal depth, BI: Bleeding Index, PI: Plaque index, R: recession)

4.6. Survival and success rate of implant

Considering figure 9 and annex 6, the success rate of implant was calculated by the number of failed implants during follow-ups. All the studies had success rate of 100% excluding study by Hana el al. (63) with success rate of 95%. The final success rate of the both techniques was 99.5%. Hence, there is no difference between 2 techniques. Implants placed by SST demonstrated 6 complications (**annex 7**), from which the most common were shield exposure and apical reabsorption compared to CI which only had 1 complication. Majority of complications were resolved after treatment to avoid implant failure. There was significant difference between in 2 groups regarding complications as the average in SST was 0.5% in SST and 0.08 in CT.

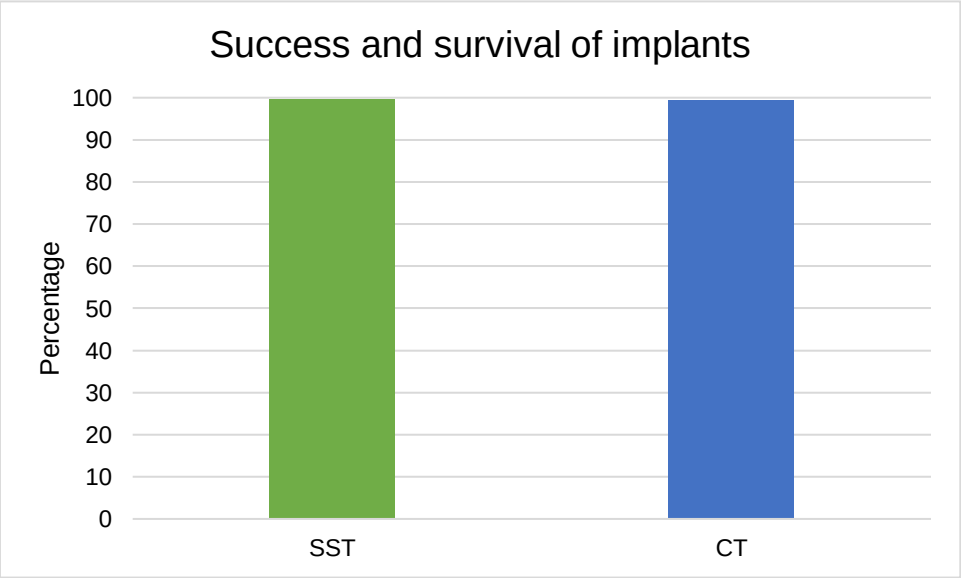

Figure 9. Success rate of implants (SST: socket shield technique, CT: conventional technique)

5. DISCUSSION

This systematic review provides evidence-based information on the outcome of socket shield technique compared to conventional technique in immediate implants. The objective of this review was to evaluate both techniques with respect to dimensional changes in horizontal and vertical bone; and secondarily to evaluate the peri-implant soft tissues according to the PES, its health status using the Bleeding Index, Plaque Index, and Pocket depth and survival rate and success of dental implants in the esthetic area. The study variable is generally same for all the articles however diagnosis method may vary. In regards to the study population, study design and sample size there is considerable amount of heterogeneity observed among the included studies.

5.1. Description of study methodology

5.1.1. Technique and measurement

In relation to the technique, significant heterogeneity was observed. The reason can be related to different modifications of SST; specifically related to shaping the buccal root at the crest level (15,28,29,61,63) o 1 mm below (26,52) or above (16,62,65). However, regarding the modifications, there was no significant differences in the result as CT had greater bone loss compared to SST. Another reason for heterogeneity was gap filled during SST and CT, 2 studies (64,65) and 7 studies (16,26,28,29,62,64,65) used biomaterial, respectively. Consequently, generalizability of finding can be problem as a consequence the conclusion of the study cannot be universalise to all surgical procedures used in SST.

In addition, measurement sites and radiographic technique were different in each study. 2 studies used periapical x-ray (26,61) for diagnosis and rest of the studies used CBCT. CBCT has higher accuracy compared to periapical as it provides 3D information which can be an important factor in diagnosis. However, PES had contributed to homogeneity as only 1 study (61) used different measurements.

5.1.2. Study population

The study population included in the present systematic review is heterogeneous. Most of the studies included tested the intervention on population with a mix of following characteristics: both male and female, intact buccal cortical bone and patients with systematic disease and heavy smokers were excluded.

Some studies excluded the smokers or heavy smokers. Since tobacco is a crucial factor for tooth loss in general population, the outcome of the intervention will be affected. Furthermore, most of the studies excluded systemic disease, even the controlled systemic diseases. High number of the population have systematic disease such as diabetes type I and arterial hypertension. So, for this present systematic review, using studies that did not have a general representative population makes it difficult to make general conclusive statements.

5.1.3. Study design

Although 8 studies included in this systematic review are RCTs, the designs of the studies vary greatly. The aleatory process used in the studies included stratified block randomization (15) and simple randomization such as the computer-generated sequence (16,26,28,29). Additionally, few RCT didn´t specify the method used and a pilot study included coin-flip method. Simple randomization is based on randomly assigning participants in a single sequence without considering certain characteristics such as age, gender or risk factors. Therefore, with this technique, it can lead to uneven distribution of influential characteristics. For instance, there can be significant of patients with bad oral hygiene and decrease in labial bone in control group compared of test group. Inevitably, this can skew the results especially if an intervention is being tested and not the factors associated to the disease. The stratified block randomization system is notably the best randomization method to implement for the studies included in the present systematic review. This system assigns an equal number of participants to groups and addresses influential characteristics accordingly. Therefore, it guarantees a homogenous distribution of participants and eliminate risk of bias.

Abd-alrahman et al.'s (15) study was the only study that implemented the stratified block randomization. Judging by the sample size and method characteristics of the participants, this randomization technique guarantees the distribution of the participants in the most homogenous and non-bias manner.

5.1.4. Follow up

All the studies included in the present systematic review had a follow of at least 3 months. Follow up period is relevant since it provides evidence of treatment efficiency and the level of compliance of the participants. Period of 3 months is sufficient to determine the bone loss after the surgery in the early stage as the immediate bone loss is more prominent comparted to late bone loss. A study by Assery et al. (67) with a follow up of 22 years to measure bone loss throughout the years revealed the mean difference was 0.88±0.017 mm from baseline to 1 year of the examination and 0.40 ±0.027 mm between 1 year and 5-year of follow up. Hence, excluding study by Kumar et al. (61), all other studies had followed up of ≥ 6 months, even 1 article with 36 months of follow up(26). As regarding PES score, short term studies determine the initial retraction of gingiva. Regardless, midterm studies are important because as the time passes, addition to bone reabsorption, it can also produce retraction of the papilla and the gingiva leading to decrease in gingival aesthetics. Therefore, with 12 studies with different follow up superior were sufficient to determine the midterm and short-term results.

5.1.5. Sample size

Great variations were also observed in the sample size participants in the included studies. An inclusion criterion with a minim of 10 patients was followed to select the studies. This number is important as it presents more reliable results. In this systematic review, excluding Tiwari el al. (52) (16 patients), all other studies had ≥ 20 patient, even 4 studies with ≥ 40 patients. In terms of the study groups, the number of participants and implants in the control and test groups was generally even. Therefore, there was no disparity between 2 techniques.

5.2. Summary of the main results

In patients requiring anterior dental implant, it was documented that SST can be effective in reducing bone loss and increasing esthetics. The aim of this study was to compare the efficacy of the SST with CT, whether it produced or not the better results regarding marginal bone loss, pink esthetic score, complication, and survival of the implant.

This review comprised a total of 12 articles that compared SST and conventional technique in immediate implants. The results obtained in the present study confirmed the hypothesis stating that SST will obtain better results compared to conventional technique vestibular bone loss, PES, and peri-implant soft tissues in Immediate implant in postextraction sites. The SST seems to have positive effects on the changes in the width and height of buccal bone plate and esthetic outcomes as demonstrated by significantly fewer changes in bone levels and higher pink esthetic score at different time points. However, there is no significant difference between dental implant failure. The study methodology for each included study is pertinent in order to deduce whether specific factors such as the study design or sample size may influence the reproducibility of the study as well as its outcome.

5.3. Marginal bone loss

Alveolar bone changes throughout the entire life (6). However, the bone reabsorption mainly is related to loss of periodontal ligament. For that reason, it can be assumed that preserving PL in the buccal portion of the root avoids the physiological absorption of the buccal wall which is usually triggered by conventional tooth extraction. Therefore, it can contribute to the preservation of vestibular bone and peri-implant soft tissue hence, improving esthetics (34). All the studies of the present systematic review demonstrated the benefits of using SST, as observed in graphic 6 and 7 which indicated higher bone loss in CT compared to SST. On average, CT had 0.45 and 0.62 greater bone resorption in horizontal and vertical, respectively. Hence, this demonstrates that the buccal root fragment helps to conserve periodontal ligament which reduces bone reabsorption process of periimplant tissue. A systematic review by Saez Alcaide

et al. comparing socket shield technique and conventional technique, revealed the same results as this study (12). However, the importance of these values is dependent on various factors, the first being whether the differences observed were statistically significant or not.

In a study by Atef et al. (28) had the highest bone loss compared to other studies. In this study, CT had an additional loss of 1.35 mm and 1.16 mm vertical and horizontal bone, respectively compared to SST. The study by Abd-alrahman el al. (15) reported the horizontal bone loss of 0.28 mm and 0.12 mm for the control and study group while the range of the vertical bone loss was 0.77 mm and 0.34, respectively. This study is supported by Chen and Pan et al. (68) and the study by Baumer et al. (33) with 58 months of follow up, which evaluated marginal bone loss though intraoral radiographs and showed bone resorption between 0.17-0.33 mm. Furthermore, a study by Nguyen et al. (23) in a case series of 3 patients using SST, demonstrated horizontal bone reabsorption of 0.1 mm after 2-6 years of follow up. This shows the difference in stability of the hard tissue between SST and CT as all the studies using SST displayed reduction in marginal bone loss.

Regarding horizontal bone loss, Kumar el al. (61), demonstrated the highest bone reabsorption 0.73 by using SST. If compared to other studies, all were inferior to 0.29. Moreover, a study by Bramanti et al. (26) demonstrated better results in SST compared to CT after 36 months of follow up. However, the difference between SST and CT was not significant. In the both studies (26,61), it can be due to radiological diagnosis as it uses periapical x-rays to measure follow up as it is not as accurate compared to CBCT as all the other studies used CBCT.

There was statistical difference between vertical and horizontal bone, as vertical bone had higher reabsorption 0.33 compared to horizontal bone 0.18 using SST technique and the same can be said for the conventional technique. Same results are demonstrated in 2 systematic reviews displaying higher bone loss in vertical bone (60,69). It can be also due to the fact that vertical bone loss in more probable in immediate implants compared to horizontal bone loss. However, according to review carried out by Lee et al. there is more bone in

volume in the horizontal dimension than vertical (70). Hence, it can be also related to the measurement technique as each study uses different points and references for measurement.

5.4. Soft tissues

Pink esthetic score takes in to account the mesial and distal papilla insertion level, the soft tissue level and contour, the alveolar process deficiency and the soft tissue color and texture (56). All the studies using SST obtained higher PES compared to CT. The average of the high PES could be due to the less volumetric alterations of the soft tissues and, therefore, to maintain the marginal bone surrounding the immediate dental implants with SST.

In study by Abd-elrahman et al. (15), Kumar et al. (61) and Hana et al. (63) using CT, observed the lowest PES score 8.85, 9.61 and 9.63, respectively. PES was 3.15, 3.17 and 2.63 higher in SST compared to CT. It can be due to the gap, which was not filled with biomaterial in CT as it is really important to avoid bone reabsorption that directly leads to soft tissue retraction in conventional technique. A study by Paknejad et al. (71) revealed 0.36 mm less reabsorption in labial bone using biomaterial compared to control group. The difference was not significant in 4 studies(16,28,29,62), being lower than 1. Moreover, Baümer et al. (33) stated minimal changes in relation with the gingival contour and few recessions were observed showing compatibility with peri-implant health. Beyond that, Hinze et al. (72) with a follow-up of 3 months demonstrated volumetric changes minor to 0.5 mm in all cases.

Esthetics is directly related to patients' satisfaction as the definition of esthetic is different to each patient. In this systematic review, 4 studies calculated patient´s satisfaction (28,29,64,65). Based on these studies it is clear SST did show better results compared to CT. Yan et al. (73) and Sapundziev et al. (74) supported this result as it also demonstrated higher patients' satisfaction. changes.

Therefore, in this systematic review, the average of PES score is 1.7 higher compared to CT. This demonstrated that PES score in general is better in

SST, which reduced soft tissue retraction. It reduces gingival retraction and black triangles in papilla leading to better esthetics and satisfaction of the patient.

Regarding, plaque index, bleeding index and periodontal depth, all the studies using SST showed better results compared to CT. This is an important factor related to bone loss and esthetics. Furthermore, as retained root improves periodontal measurement, hence reduces bone loss and inflammation of soft tissues

5.5. Survival and success rate of implant

All the studies had a success rate of 100% with an exception of 1 article. This shows that using SST had the final success rate of 95%, similar to CT. The only study with implant failure was by Hana el al, (63) with 1 implant failure in each technique. In comparison to study by Gluckman et al., which demonstrated 96.1% of survival rate with 4 years of follow up (44).

Regarding complications, the most frequent complication in SST is internal and external shield exposition. In the study by Abd-elrahman et al. (15) showed 1 internal shield exposure, Tiwari et al. (52) 1 apical reabsorption, Kumar et al. (61) 1 shield exposure and Hana el al. (63) shield exposures. The exposures were treated by maintenance of soft tissue without the need to use other alternatives. However, a clinical case presented by Zuhr et al., reveled shield exposure and the defect was filled by bovine bone particle (75). On the contrary, the complication related to CT in 5 implants is inadequate keratinized tissue and gum recession (63). Furthermore, the treatment is more complex as soft tissue grafts were used to manage this complication.

5.6. Other systematic reviews

The first systematic review was done by Saez Alcaide et al. comparing socket shield technique and conventional technique. However three of the seven studies used in these articles, only had 1 patient which is insufficient to determine the outcome (12). Second systematic review doesn't solely compare conventional and SST but also contain other studies, which compare these techniques individually. Hence, the number of implants, patients, and techniques are different between in each article. This can increase the heterogeneicy in the

review (69). Third study, didn`t include 4 important articles that gives ample information about the outcome of these techniques (60).

5.7. Limitations

Despite the results obtained from the studies, some limitations can be observed to reach firm conclusion. There were no studies with follow up superior to 3 years hence, the conclusions are related to short or midterm studies. It is important to increase the follow-up to 5-10 years for long term results. These results are important to determine possible late complications that can appear in 10-15 years. This can also help us to modify the technique to increase the success rate of the implant. Furthermore, lack of homogenicy was observed in evaluation methods and surgical technique. Each author modified the original technique, specifically related to shaping the buccal root at the crest level o 1 mm below or above. However, regarding the modifications, there was no significant differences in the result as CT had greater bone loss compared to SST in all the studies. Hence, a universal technique can increase the success factor of the implant as it can avoid the heterogeneity in future. The measurement of the buccal bone in the follow up differs in each study. There is a need to stablish a protocol on measurement of the buccal bone in SST. Moreover, there is no specific evaluation criteria to evaluate the success rate of the socket shield technique as the criteria used by the authors is same as used for the standard implant. We believe that tissue surrounding using SST is different to CT. Therefore, there should be a specific criterion for this technique as retaining buccal shield is an important factor which is not mentioned in the criteria for the standard implant. The radiographs used for evaluation differs in articles as some studies used periapical and others CBCT. CBCT is recommended as it provides 3D information. Using periapical can lead to inaccurate evaluation of the bone.

The studies included in this systematic review had a specific criterion for inclusion and exclusion. In the most of the studies the buccal bone should be intact, some studies mention bone width >1.5 mm or 1 mm. Hence, these studies can’t be generalizing the entire population as majority of people have buccal bone <0.5 mm. The risk of bias of these articles was not low. As only 1 article had low

risk of bias. This demonstrates that these articles didn´t follow the strict criteria for randomized controlled studies and observational studies.

More RCT are needed following the strict criteria for lower risk of bias and with follow-up between 10-15 years for long term studies in order to accurately compare the results obtained. Furthermore, it is important to stablish a universal success criterion, evaluation methods and surgical technique to avoid heterogeneity in the future systematic reviews.

Conclusions

The present systematic review aimed to compare socket shield technique and conventional technique with the intention to evaluate the changes in vestibular bone, pink esthetic score, periodontal index and success and survival of the implant.

Primary conclusion

- Socket shield technique demonstrated lower horizontal and vertical bone reabsorption in vestibular comparted to conventional technique

Secondary conclusion

- Socket Shield technique demonstrated higher pink esthetic score and lower bleeding index, plaque index and periodontal depth compared to conventional technique.
- Socket shield technique demonstrated no difference in respect to convectional technique in the survival and success rate of the implant.

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ANNEX

Socket shield technique vs conventional technique in immediate implants in the esthetic zone. A systematic review

Socket shield technique vs Conventional technique

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ABSTRACT

- Objectives: Evaluate dimensional changes of the vestibular bone (vertical, horizontal, or both), as well as to study secondarily pink esthetic score (PES), periodontal health status using the Bleeding Index (BI), Plaque Index (PI), and Pocket depth (PD) and survival and success rate in socket shield technique (SST) compared to conventional technique (CT) in the esthetic area in immediate implant in postextraction sites
- Materials and Methods: Following the recommended methods for systematic reviews (PRISMA), an electronic search was conducted in the MEDLINE COMPLETE, Web of Science, Scopus and Embase databases to identify all relevant articles published up until November 2021 on SST and CT.
- Results: Of 200 potentially eligible items, 12 complied with the inclusion criteria. There is significant difference between 2 techniques as the mean average of SST in horizontal and vertical bone loss was 0.18 and 0.33, respectively compared to CT, which was 0.63 and 0.95. The average PES of SST was 1.7 higher to CT. All the periodontal measurements were higher in CT compared to SST. The success rate of the both techniques was 99.5%.
- Discussion: Despite the results obtained from the study some limitations can be observed to reach firm conclusion. There are no studies with follow up superior to 3 years hence the conclusions are related to short or midterm studies. In addition, lack of homogenicy was observed in evaluation methods and surgical technique. Moreover, there is no specific evaluation criteria to evaluate success as the criteria used in this systematic review is same as used for standard implant.
- Conclusions: Socket shield technique has lower horizontal and vertical bone reabsorption in vestibular, higher pink esthetic score and same success rate comparted to conventional technique.

Keywords*: Dental implantation*, *Immediate implant*, *Immediate dental implant loading*, *Labial bone thickness*, *Socket shield technique*, *Esthetics*, *Alveolar bone loss*, *Bone reabsorption*

1. INTRODUCTION

Immediate implant is defined as an implant placed after tooth extractions in the same surgical procedure (1). One of the main advantages of the immediate implant technique is to provide a high level of esthetics for the patients in a short time (2). Despite all these advantages, there is bone reabsorption, related to loss of periodontal ligament; therefore, it can be assumed that preserving PL in the buccal portion of the root, avoids the physiological absorption of the buccal wall which is usually triggered by convectional tooth extraction. Socket shield technique is a technique introduced by Hurzler et al. (3) in which a small labial coronal fragment of the root is maintained in place to preserve the blood supply reaching the facial cortical plate from the periodontal ligament and an immediate implant is placed palatal to the root fragment (4–6). The second study using SST in humans was reported by Siorpmos et al. (7) in 2014 and in continuation, Gluckman et al. (8) in 2018, et al proposed modification of SST technique, renamed partial extraction therapy.

In the last 5 years, there was an increase in the number of studies indicating SST as an alternative to maintain marginal bone, peri-implant soft tissues, and implant stability (4,6,9,10). The relevance of this systematic review is to allow dentists to carry out this technique as routine in everyday practice safely taking into account all the risk factors and possible complications. For this reason, this systematic review was developed to evaluate the efficiency in terms of bone loss (horizontal and vertical), esthetics of peri-implant soft tissue and survival and success rate of implant in SST compared to the conventional technique in the esthetic area in immediate implant in postextraction sites.

2. MATERIALS AND METHODS

Protocol and focused question: The present systematic review was carried out according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). The following focus question was employed according to the population, Intervention, c: In the patients with immediate implant in the esthetic

zone (P), does the socket shield technique (I) improve clinical outcome in terms of dimensional changes in width and height of the vestibular bone, changes in the peri-implant soft tissue, pink esthetics score, survival and success rate (O) compared to conventional technique (C)

Selection criteria: Studies were excluded based on the following criteria: studies more than 5 years, and on animals. The inclusion criteria involve studies on SST and CT. Studies that will provide data related to dimensional changes to the buccal bone as the main variable. Variable collected as secondary: esthetics using the pink esthetic score, soft tissue evaluation such as Periodontal depth, bleeding index and plaque index, survival and success rate of dental implants, and post-operatory problems. Only randomized control trial (RCT) and observational studies were included. Minimum follow-up of 3 months. Minimum number of 10 patients.

Search strategy: The database Medline complete, Web Of Science, Cochrane and Scopus were used to search the indexed articles on patients requiring immediate implants using socket shield technique or conventional technique, published up to 30 December 2021. The algorithm used for the search is the following: (Immediate Dental Implant Loading OR Dental Implantation OR Dental Implants OR Immediate implant) AND ("socket shield technique" OR "root membrane technique" OR "partial extraction therapy" OR "PDL root maintenance") AND (Alveolar Bone Loss OR bone resorption OR esthetics dental OR labial bone thickness).

Screening methods and data collection process: A three-stage selection process was carried out. The selection of studies was carried out by 2 reviewers (KKS & EW) In the first screening, relevant articles were selected based on title and abstract. Irrelevant articles were then excluded based on the exclusion criteria. The second screening, consisted of reading the full texts of the articles included in the first screening phase. Articles were then excluded based on inclusion criteria. The data was extracted from the studies for SST and CT and set out in a excel document.

Risk of bias in individual studies: To assess the quality of the studies included in this review, the ROBINS-I (The Risk of Bias in Non-Randomized Studies) tool was used for the observational studies and the RoB-2 (Cochrane Method Bias) tool for the randomized clinical trials. The report was assessed by the first reviewer (K.K.) and verified by the second reviewer (E.L.W.).

Data synthesis: In order to summarize and compare studies, values of the variables were grouped into each study group and then analyzed using the weighted average. The average was done by the sum of bone loss or pink esthetic score or periodontal measurements for each study divided by number of studies. The success rate was determined by success percentage in each article divided by number of articles.

RESULTS

Study selection: A total of 200 articles were obtained from the initial search process: Medline complete (n=30), Web of Science (n=51), Scopus (n= 100) and Embase (n=19. Of these publications, 10 were identified as potentially eligible articles after screening by titles and abstracts. The full text articles were subsequently obtained and thoroughly evaluated and 1 study was excluded. In addition, 3 studies were found through manual search (Journals and cross search). As a result, 12 articles met the inclusion criteria and were included in this systematic review (Fig 1).

Characteristics of included studies: 12 studies were included in this systematic revision as explained in the table 1, all the studies comparing conventional and SST technique. 7 studies were randomized controlled comparative clinical study (11–18), 1 prospective non randomized clinical trial (19), 1 retrospective comparative study (20), 1 prospective comparative study (21), and 1 a pilot study (22). Marginal bone loss was measured in 11 studies (11–19,21,22). Of all these studies, 4 measured vertical and horizontal bone loss (11,14,15,18), 2 measured vertical bone loss (12,21) and 5 measured horizontal bone loss (13,16,17,19,22). Therefore, 9 (11,13–19,22) and 6 studies (11,12,14,15,18,21) were included in horizontal and vertical bone loss, respectively. Moreover, 10 studies measured PES (11,12,15–22).

Risk of bias: All included studies were evaluated according to the Cochrane Collaboration tool in figure 2A and 2B, summarizes this analysis. The overall risk-of-bias judgment for randomized controlled trail included in the present systematic review was low in 1 study (15), some concern in 5 studies (12,13,16–18) and high in 2 studies (11,14). In observational studies, the overall risk-of-bias judgment was moderate in all the studies.

Marginal bone loss: The degree of reabsorption and changes in labial bone thickness is observed in figure 3A and 3B. In respect to horizontal and vertical bone loss, all the studies demonstrated greater bone loss in CT compared to SST. The bone reabsorption of two techniques was between 0.03 to 1.71. There was significant difference between 2 techniques as the mean average of SST in horizontal and vertical bone loss is 0.18 and 0.33, respectively compared to CT, which is 0.63 and 0.95. Therefore, the differential average between 2 technique was significant as CT demonstrated additional 0.45 and 0.62 bone reabsorption in vertical and horizontal, respectively. There was significant difference between horizontal and vertical bone loss. Regarding CT, 4 studies in horizontal (17–19,22) and 3 in vertical (14,15,18), demonstrated higher bone loss than 0.8. Considering SST, no studies demonstrated bone loss higher than 0.8 in horizontal and vertical bone.

Pink esthetic score and periodontal parameters: In respect to SST (Figure 4), 8 studies had PES score higher than 12 (11,12,15,17–20,22), whereas comparted to CT, where no score was above 12. As for the data extracted from the studies, the average of PES of SST is 12,3 compared to CT, whose average is 10.6. Therefore, the average PES of SST is 1.7 higher compared to CT. All the studies using SST had higher PES score compared to CT. There was significative difference in PES score between 2 techniques in 6 studies, indicating CT PES score difference of more than 1 compared to SST (11,12,17,19,20,22). However, 4 studies demonstrated no significate difference as the difference between the 2 techniques was less than 1 (15,16,18,21). In respect to periodontal measurement; bleeding index, plaque index and periodontal depth, all the periodontal measurements in all the articles, were higher

in CT compared to SST.

Survival and success rate of implant: Considering figure 9 and annex 5, the success rate of implant was calculated by the number of failed implants during follow-ups. The final success rate of the both techniques is 99.5%. Hence, there is no difference between 2 techniques.

3. DISCUSSION

This review comprised a total of 12 articles that compared SST and conventional technique in immediate implants. The results obtained in the present study confirmed the hypothesis stating that SST will obtain better results compared to conventional technique vestibular bone loss, PES, and peri-implant soft tissues in Immediate implant in postextraction sites.

Methodology: This systematic review provides evidence-based information on the outcome of socket shield technique compared to conventional technique in immediate implants. In relation to the technique, significant heterogeneity was observed. The reason can be related to different modifications of SST; specifically related to shaping the buccal root at the crest level (11,16,18,20,22) o 1 mm below (12,13) or above (15,19,21). In addition, measurement sites and radiographic technique were different in each study. 2 studies used periapical x-ray (12,22) for diagnosis and rest of the studies uses CBCT. CBCT has higher accuracy compared to periapical as it provides 3D information which can be important factor in diagnosis.

Marginal bone loss: All the studies of the present systematic review demonstrated the benefits of using SST, as observed in graphic 6 and 7 which indicated higher bone loss in CT compared to SST. On average, CT had 0.45 and 0.62 greater bone resorption in horizontal and vertical, respectively. Hence, this demonstrates that the buccal root fragment helps to conserve periodontal ligament which reduces bone reabsorption process of periimplant tissue. A systematic review by Saez Alcaide et al. comparing socket shield technique and conventional technique revealed the

same results as this study (2). Regarding horizontal bone loss, Kumar el al. (22), demonstrated the highest bone reabsorption 0.73 by using SST. If compared to other studies, all were inferior to 0.29. Moreover, a study by Bramanti et al. (12) demonstrated better results in SST compared to CT after 36 months of follow up. However, the difference between SST and CT was not significant. In the both studies, it can be due to radiological diagnosis as it uses periapical x-rays to measure follow up as it is not as accurate compared to CBCT as all the other studies used CBCT. Vertical bone had higher reabsorption 0.33 compared to horizontal bone 0.18 using SST technique and same can be said for the conventional technique. It can be also due to the fact that vertical bone loss in more probable in immediate implants compared to horizontal bone loss. However, according to review carried out by Lee et al, there is more bone in volume in the horizontal dimension than vertical (23). Hence, it can be also related to the measurement technique as each study uses different points and references for measurement.

Soft tissues: In study by Abd-elrahman et al. (11), Kumar et al. (22) and Hana et al. (20) using CT, observed the lowest PES score 8.85, 9.61 and 9.63, respectively. PES was 3.15, 3.17 and 2.63 higher in SST compared to CT. It can be due to the gap, which was not filled with biomaterial in CT as it is really important to avoid bone reabsorption that directly leads to soft tissue retraction in conventional technique. A study by Paknejad et al., (24) revealed 0.36 mm less reabsorption in labial bone using biomaterial compared to control group, Therefore, in this systematic review, the average of PES score is 1.7 higher compared to CT. This demonstrated that PES score in general is better in SST, which reduced soft tissue retraction. It reduces gingival retraction and black triangles in papilla leading to better esthetics and satisfaction of the patient.

Survival and success rate of implant: All the studies had a success rate of 100% with an exception of 1 article. This shows that using SST and CT had the final success rate

of 95%. In comparison to study by Gluckman et al., demonstrated 96.1% of survival rate with 4 years of follow up(8).

Limitations: Despite the results obtained from the study some limitations can be observed to reach firm conclusion. There are no studies with follow up superior to 3 years hence the conclusions are related to short or midterm studies. It is important to increase the follow-up to 5-10 years for long term results. In addition, lack of homogenicy was observed in evaluation methods and surgical technique. Moreover, there is no specific evaluation criteria to evaluate success as the criteria used in this systematic review is same as used for standard implant. Nevertheless, we believe that tissue surrounding using SST is different to CT. Hence, new protocol should be established to determine the success of SST.

4. CONCLUSIONS

Socket shield technique has lower horizontal and vertical bone reabsorption in vestibular, higher pink esthetic score and same success rate comparted to conventional technique

ACKNOWLEDGMENTS

Authors would like to thank Dental University Clinic of European University of Valencia and researchers for their help with this systematic review and meta-analysis.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest in this study. The study was designed, conducted and analyzed by researchers belonging to the Official Master in Advanced Oral Implantology (European University of Valencia, Valencia, Spain).

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Table 1. Characteristics of articles included in systematic review.

Author and year	Type of study	(participants/ implants)	Location and teeth	Age and sex	Variable measured (method assessment)	Follow-up
Atef et al.,2021(18)	Prospective randomized parallel two-arm controlled clinical trial	Total: (42/42) SST: (21/21) CT: (21/21)	Upper I and C Premolars	Artículo II. 6 ± 5.55 10 Males 30 Females	Horitzontal and vertical bone loss (CBCT), Soft tissue (PES) Patient satisfaction (VAS), Complications	Bone loss: 6 months PES, VAS and complications:12 months
Abd-elrahman et al.,2020(11)	Randomized control clinical trial	Total: (25/40) SST: (-/20) CT: (-/20)	Maxillary anterior teeth	30.9 ± 5.5 11 Males 14 Females	Horitzontal and vertical bone loss (CBCT) Soft tissue (PES) Implant stability (RFA), Complications	6 months
Bramanti et al., 2018 (12)	Randomized control clinical trial	Total: (40/40) SST: (20/20) CT: (20/20)	Anterior maxillary and mandibular teeth	-	Marginal (vertical) bone loss (Periapical) Soft tissue (PES) Implant stability (ostell), Complications	3,6,36 months
Tiwari et al., 2019(13)	Randomized clinical trial	Total: (16/16) SST: (8/8) CT: (8/18)	Maxillary anterior teeth	Mean age 24	Horitzontal bone loss (CBCT)	1,4,8 and 12 months
Kumar et al., 2021(22)	A Pilot study	Total: (20/30) SST: (-/15) CT: (-/15)	Maxillary anterior teeth	Mean age 37 14 Males 6 Females	Marginal bone loss horitzontal (periapical), Soft tissue (PES)	15 days and 4 months
Barakat et al., 2017(14)	Randomized Controlled Clinical Trial	Total: (20/20) SST: (10/10) CT: (10/10)	Maxilla SST: 6 I and 4 C CT: 7 I and 3 C	Mean age 35 8 Males 12 Females	Horitzontal and vertical bone loss (CBCT) Soft tissue (PD, BI) Implant stability (ostell) Complications	4 and 7 months
Sun et al.,2019 (15)	Randomized controlled clinical trial	Total: (30/30) SST: (15/15) CT: (15/15)	Anterior teeth	>25 years 7 Males 23 Females	Horitzontal and vertical bone loss (CBCT) Soft tissue (PES, PD, BI, PI, Recession) Implant stability (RFA) Complications	Bone loss (6 months) Soft tissue (6,12,24)
Santhanakrishnan et al., 2021(16)	Randomized controlled clinical trial	Total: (150/150) SST: (50/50) CT: (50/50)	Maxillary anterior teeth	30.1±8 34 Males 41 females	Horitzontal bone loss (CBCT) Soft tissue (PES)	6 months

		DIP: (50/50)			Patient satisfaction (esthetics and pain analogue): VAS, Complications	
Hana et al., 2020 (20)	Retrospective comparative study	Total: (40/40) SST: (20/20) CT: (20/20)	Maxillary anterior teeth	Mean age 51 26 Males 14 Females	Soft tissue (PES) Complications	12 months
Fattouh et al., 2018 (21)	Prospective comparative study	Total: (20/20) SST: (10/10) CT: (10/10)	Maxillary anterior teeth	>18 years old 8 Males 12 Females	Vertical bone loss (Periapical) Soft tissue (PES) Complications	Complications: 1 week, 4 week, 3,6,12 months. Other: 3,6,12 months
Zhang et al., 2020(17)	Prospective, double blind randomized controlled clinical study	Total: (60/60) SST: (30/30) CT: (30/30)	Maxilla 38 CI 22 LI	37.0+3.7 33 Males 7 Females	Horitzontal bone loss (CBCT) Soft tissue (PES) Complications Patient satisfaction: esthetics (Ruler)	12 months
Xu et al., 2019 (19)	Prospective non Randomized clinical trial	Total: (24/24) SST: (12/12) CT: (12/12)	Maxilla 20 CI 4 LI	38.08+10.5 12 Males 12 Females	Horitzontal bone loss (CBCT) Soft tissue (PES) Complications Patient satisfaction: esthetics (VAS)	12 Months

SST: socket shield technique, CT: conventional technique, I: Incisors, C: canines, CBCT: (Cone-beam computed tomography) systems, PES: Pink esthetic score, VAS: Visual analogue scale, RFA: Resonance Frequency analysis, PD: Periodontal depth, BI: Bleeding Index, PI: Plaque index, DIP: Differed immediate implant

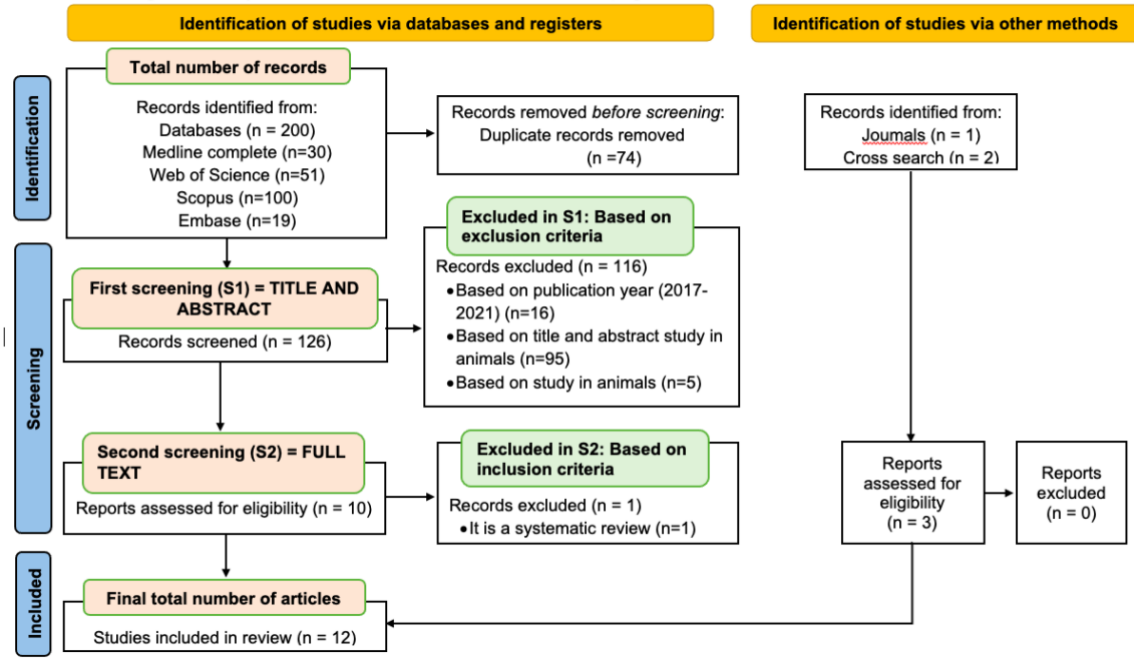

Figure 1. Study identification process and results of the literature search via databases and other methods according to PRISMA 2020

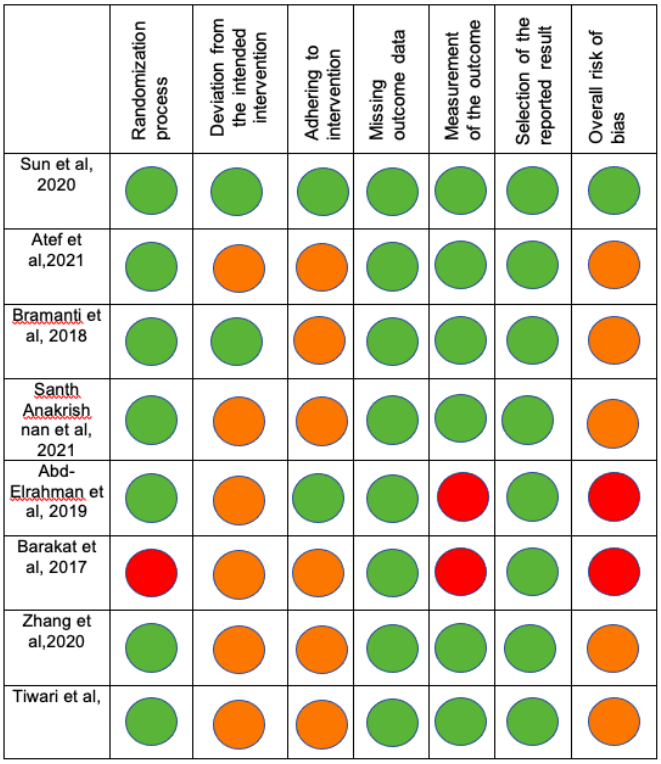

Fig 2A. Assessment risk of bias of the included RCT presented with low (green), some concerns (orange), and high (red) risk of bias

Bias assessment	Kumar et al,2021	Fattouh, 2018	Hana et al, 2020	Xu et al, 2019
·Bias due to cofounding				
Selection of participants				
Classification of intervention				
Deviations from intended interventions				
Bias due to missing data				
Measurements of outcomes				
Selection of the reported result				
Overall bias				

Fig 2B. Assessment risk of bias of the included observational studies presented with low (green), moderate (orange), and high (red) risk of bias

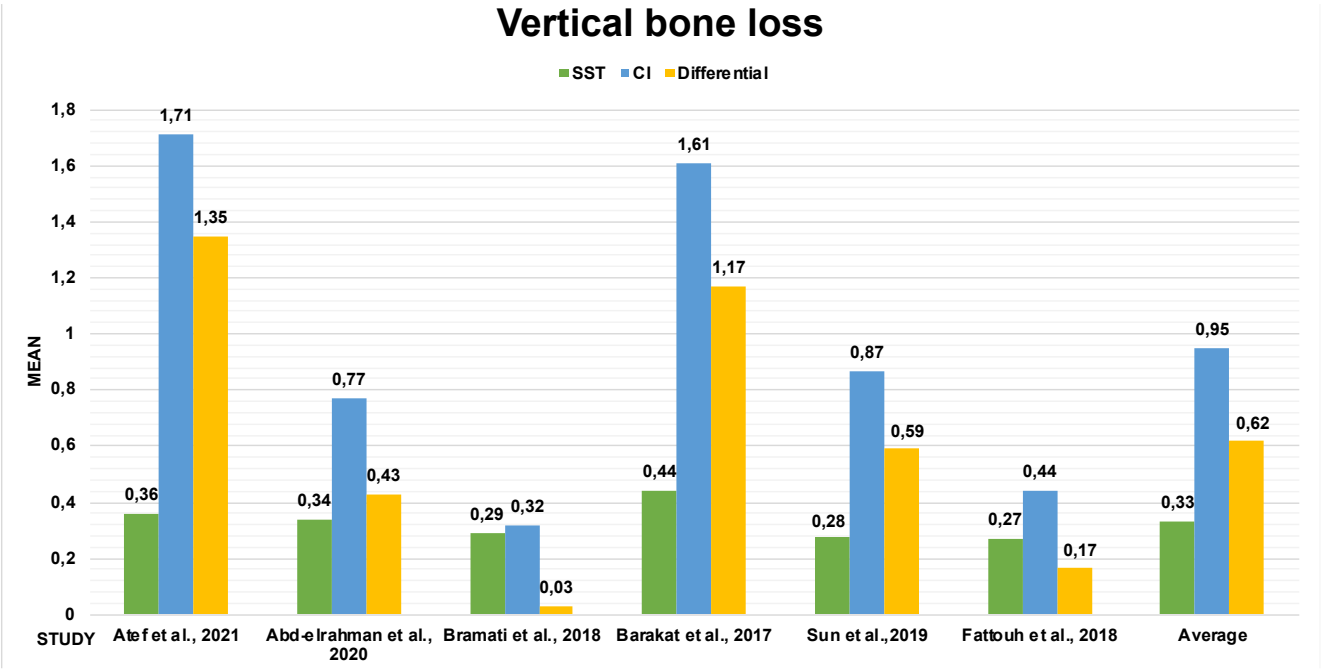

Figure 3A: Immediate implant placement with socket shield technique versus conventional technique. Degree of reabsorption: Changes in height (vertical bone loss) of buccal bone plate. (SST: socket shield technique, CI: conventional technique)

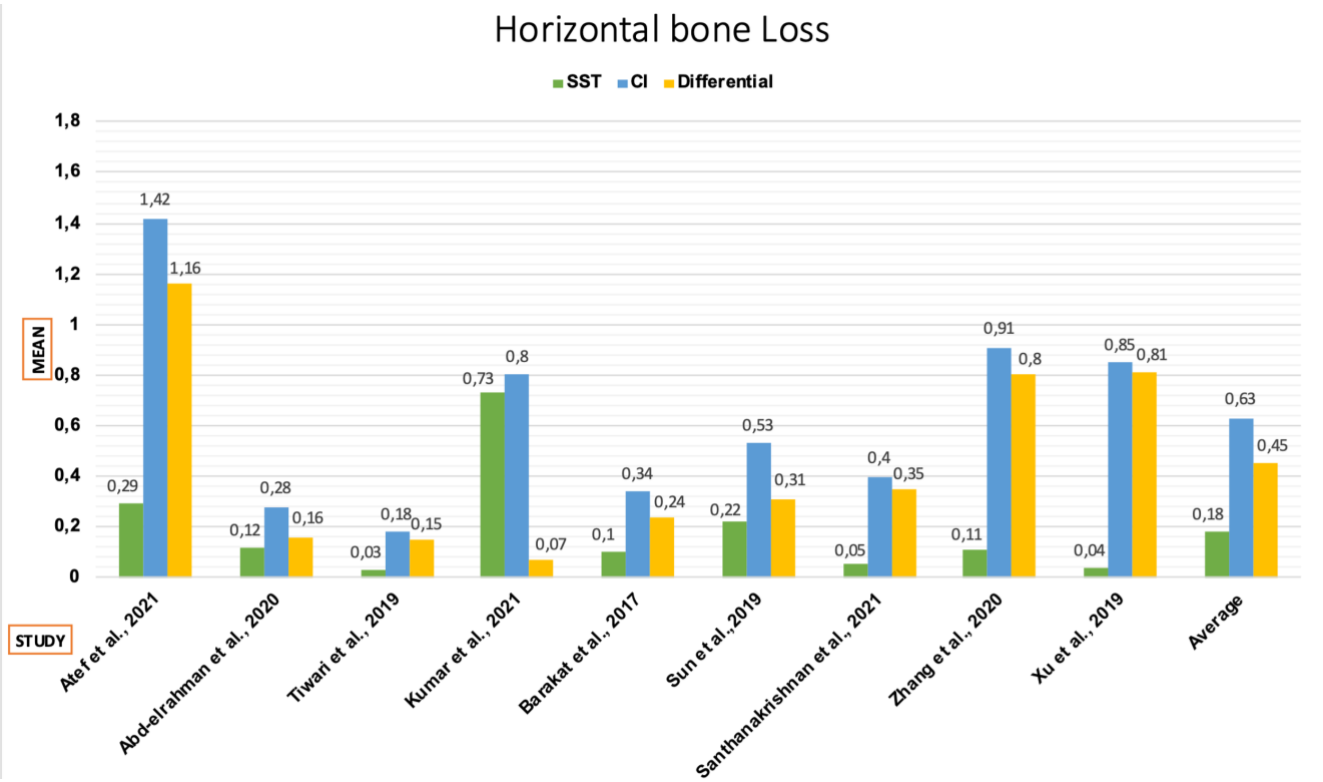

Figure 3B Immediate implant placement with socket shield technique versus conventional technique. Degree of reabsorption: Changes in width (horizontal bone loss) of buccal bone plate. (SST: socket shield technique, CI: conventional technique

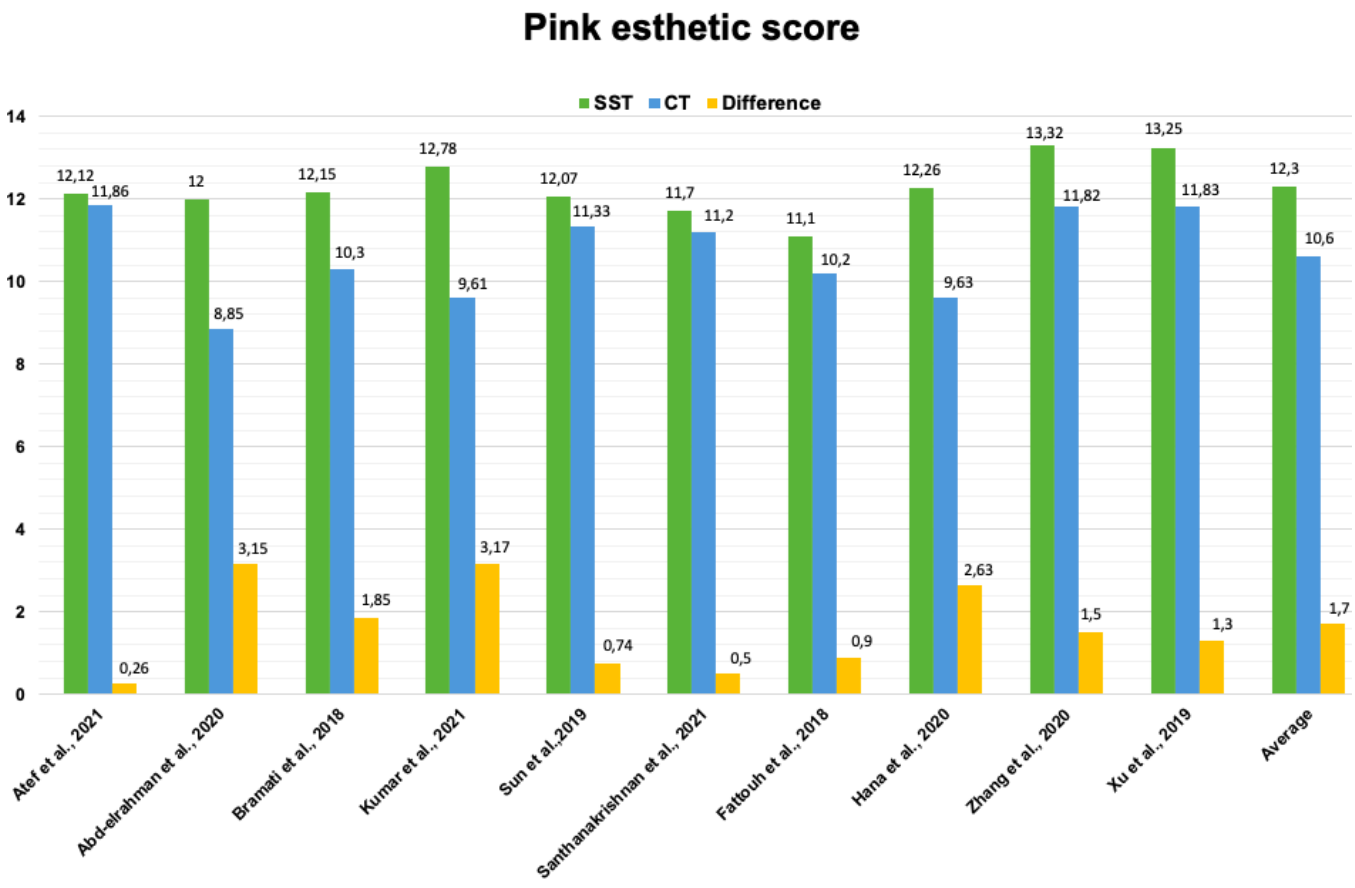

Figure 4. Immediate implant placement with socket shield technique versus conventional technique. Changes in Pink esthetic score. (SST: socket shield technique, CI: conventional technique

Annex 2. Prisma checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	12
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	13
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	14
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	14
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	16
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	17
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	18
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	N/A
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	N/A
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	19
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	N/A
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	22
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	N/A
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	N/A
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	N/A
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	N/A
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	N/A
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	N/A

Section and Topic	Item #	Checklist item	Location where item is reported
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	N/A
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	21
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	21
Study characteristics	17	Cite each included study and present its characteristics.	22
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	24
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	28
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	N/A
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	N/A
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	N/A
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	N/A
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	N/A
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	N/A
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	36-40
	23b	Discuss any limitations of the evidence included in the review.	33-35
	23c	Discuss any limitations of the review processes used.	40
	23d	Discuss implications of the results for practice, policy, and future research.	41
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	N/A
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	N/A
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	N/A
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	N/A
Competing interests	26	Declare any competing interests of review authors.	N/A
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	N/A

Annex 3. Immediate implant placement with socket shield technique versus conventional technique. Degree of reabsorption: Changes in width (horizontal bone loss) and height (vertical bone loss) of buccal bone plate.

SST: socket shield technique, CT: conventional technique, Dif: difference

	Horizontal bone loss			Vertical bone loss			Total implants	Follow up
	SST	CI	Dif	SST	CI	Dife	SST/CT	
Study	Mean	Mean	Dif	Mean	Mean	Dif		
Atef et al., 2021	0.29	1.45	1.16	0.36	1.71	1.35	21/21	6 months
Abd-elrahman et al., 2020	0.12	0.28	0.16	0.34	0.77	0.43	20/20	6 months
Bramanti et al., 2018	-	-	-	0.29	0.32	0.03	20/20	36 months
Tiwari et al., 2018	0.03	0.18	0.15	-	-	-	16/16	12 months
Kumar et al., 2021	0.73	0.8	0.07	-	-	-	15/15	4 months
Barakat et al., 2017	0.1	0.34	0.24	0.44	1.61	1.17	10/10	7 months
Sun et al.,2019	0.22	0.53	0.31	0.28	0.87	0.59		6 months
Fattouh et al., 2018	-	-	-	0.27	0.44	0.17	10/10	12 months
Santhanakrishnan et al., 2021	0.05	0.4	0.35	-	-	-	50/50	6 months
Zhang et al., 2020	0.11	0.91	0.8	-	-	-	30/30	12 months
Xu et al., 2019	0.04	0.85	0.81	-	-	-	12/12	12 months
Average	0.18	0.63	0.45	0.33	0.95	0.62		

Annex 4. The radiographs for bone measurements for each study in SST and CT

Autor	Radiographs	Methods of measurement
Atef et al.,2021(27)	CBCT	1. Immediately after surgery 2. 6 months after surgery
		Vertical: distance from the implant platform to the buccal alveolar crest at the midbuccal implant surface Horitzontal: distance between the implant and the outer surface of the buccal plate at the midbuccal implant surface 1 mm below the buccal crest
		Degree of reabsorption
Abd-elrahman et al.,2020(15)	CBCT	1. Immediately after surgery 2. 6 months after surgery
		Vertical: Starting from the implant shoulder, perpendicular lines were drawn to the bone crest labially and palatally and the average was recorded for each implant in both groups Horitzontal: a line was drawn intersecting the implant apex and perpendicular to the implant shoulder. From that line, another line was drawn to the outer margin of the labial plate of bone to record the horizontal bone level for each implant in both groups.
		Degree of reabsorption
Bramanti et al., 2018(25)	Periapical	1. Immediately after surgery 2. 3 months after surgery 3. 6 months after surgery 4. 36 months after surgery
		Method of Kotsakis
		Degree of reabsorption

Tiwari et al., 2019(52)	CBCT	1. Immediately after surgery 2. 1 month after surgery 3. 8 months after surgery 4. 12 months after surgery
		The labial cortical thickness was evaluated along its entire length at the following distances from the crest. 4 points: 0 mm at the crest, 3 mm apical to the crest, 6 mm apical to the crest and 9 mm apical to the crest.
		Labial bone thickness
Kumar et al., 2021(61)	Periapical	1. 15 days after surgery 2. 4 months after surgery
		Measurements were noted between the proximal crestal bone level and the implant platform both mesially and distally
		Degree of reabsorption
Barakat et al., 2017(66)	CBCT and OPG	1. Presurgery (periapical and OPG) 2. Immediately after surgery 3. 4 months after surgery 4. 7 months after surgery
		Starting from the implant shoulder a fixed distance was taken as a reference line and the horizontal bone level was measured. A line from the apex of the implant parallel to the reference horizontal line of the CBCT was drawn and the marginal bone level was measured from the reference line to the marginal bone crest parallel to the implant.
		Degree of reabsorption
Sun et al.,2019(28)	CBCT	1. Presurgery 2. 6 months after surgery

		A reference line was drawn parallel to the buccal plate. The buccal plate width (BPW) was measured by tracing a perpendicular line from this reference at the junction with a line overlapping the 5th thread of the implant. The BPW at the 5th thread level was regarded as the mean BPW. The buccal plate height (BPH) measurement was obtained by tracing the vertical distance from the most apical alveolar crest to the implant shoulder line
		Labial bone thickness
Santhanakrishnan et al., 2021(29)	CBCT	1.Pre surgery 2. 6 months after surgery
		Pre-operative and post-operative measurements were done using a standard reference point acquired by a line drawn parallel to the inner aspect of the facial alveolar plate to intersect the floor of the maxillary sinus/nasal floor. The thickness of the facial cortical plate was measured 1 mm from the coronal most aspect of the facial bone crest, evaluated in cross-sections using 1 mm sections with the distance measurement tool in the pre-operative labio- palatal direction.
		Labial bone thickness
Fattouh et al., 2018 (62)	CBCT and Periapical	1. Pre surgery (CBCT) 2. Immediately after surgery (periapical) 3. 3 months after surgery (periapical) 4. 6 months after surgery (periapical) 5. 12 months after surgery (periapical) The distance was measured from the mesial and distal margin of the implant neck to the most coronal point where the bone or the root appeared to be in contact with the implant

		Degree of reabsorption
Zhang et al., 2020(64)	CBCT	1. Pre surgery 2. Immediately after surgery 3. 12 months after surgery
		The thicknesses of labial bone plates of 1, 3, and 5 mm were recorded from the crest.
		Labial bone thickness
Xu et al., 2019 (65)	CBCT	1. Pre surgery 2. Immediately after surgery 3. 12 months after surgery
		3 points: The thickness of the labial bone of the crest, the thickness of the labial bone of 2 mm at the crest and thickness of the labial bone of 4 mm at the crest.
		Labial bone thickness

Annex 5. Immediate implant placement with socket shield technique versus conventional technique. Changes in Pink esthetic score

	PINK ESTHETIC SCORE						
	SST		CT		Difference	Total	Follow up
Study	Mean	SD	Mean	SD			
Atef et al., 2021	12.12	0.64	11.86	0.35	0.26	21/21	12 months
Abd-elrahman et al., 2020	12	1.12	8.85	1.81	3.15	20/20	6 months
Bramanti et al., 2018	12.15	0.87	10.3	1.59	1.85	20/20	36 months
Kumar et al., 2021	12.78	1.03	9.61	1.35	3.17	15/15	4 months
Sun et al.,2019	12.07	1.62	11.33	1.76	0.74	15/15	24 months
Santhanakrishnan et al., 2021	11.7	1.8	11.2	2.1	0.5	50/50	6 months
Fattouh et al., 2018	11.1	0.73	10.2	0.42	0.9	10/10	12 months
Hana et al., 2020	12.26	1.04	9.63	1.34	2.63	20/20	12 months
Zhang et al., 2020	13.32	1.25	11.82	1.03	1.5	30/30	12 months
Xu et al., 2019	13.25	0.75	11.83	0.94	1.3	12/12	12 Months
Average	12,3	-	10.6	-	1.7		

SST: socket shield technique, CT: conventional technique, SD: standard deviation

Annex 6. Survival and success rate in Immediate implant placement with socket shield technique versus conventional technique

	Complications		Survival of implants		Follow up
	SST	CT	SST	CT	
Study					
Atef et al., 2021	0	0	100%	100%	12 months
Abd-elrahman et al., 2020	1	0	100%	100%	6 months
Bramanti et al., 2018	0	0	100%	100%	36 months
Tiwari et al., 2019	1	0	100%	100%	12 months
Kumar et al., 2021	1	0	100%	100%	4 months
Barakat et al., 2017	0	0	100%	100%	7 months
Sun et al.,2019	0	0	100%	100%	24 months
Santhanakrishnan et al., 2021	0	0	100%	100%	6 months
Fattouh et al., 2018	0	0	100%	100%	12 months
Hana et al., 2020	3	1	95%	95%	12 months
Zhang et al., 2020	0	0	100%	100%	12 months
Xu et al., 2019	0	0	100%	100%	12 Months
Media ponderada	0.5%	0.08%	99.5%	99.5%	

SST: socket shield technique, CT: conventional technique,

Annex 7. Complications and treatment related to SST and CT

Study	Number of implants	Complications	Treatment
Abd-elrahman et al., 2020	40	SST: 1 Internal shield exposure	There was no inflammatory signs hence no corrective treatment was required
Tiwari et al., 2019	16	SST: 1 apical rebsorption	N/A
Kumar et al., 2021	20	SST: 1 shield exposure	The shield was trimmed gently
Hana et al., 2020	40	SST: 1 implant failed 1 internal reabsorption 1 external reabsorption	Reduction of the exposed fragment with managing of soft tissue
		CT: 1 implant failed 5 inadequate keratinized tissue band and gum recession	Soft tissue grafts done about 1 year later