Journal of Oral Implantology

Current Evidence on the Socket-Shield Technique: A Systematic Review

--Manuscript Draft--

Manuscript Number:	aaid-joi-D-17-00118R1
Full Title:	Current Evidence on the Socket-Shield Technique: A Systematic Review
Short Title:	A Systematic Review on the Socket-Shield Technique
Article Type:	Review Paper
Keywords:	dental implant; Dental Cementum; Periodontal Ligament; Socket-Shield; Systematic Review; Complications; Adverse effects
Corresponding Author:	Amit Srikant Gharpure, B.D.S, Advanced Education in Restorative Dentistry Rutgers School of Dental Medicine Newark, New Jersey UNITED STATES
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Rutgers School of Dental Medicine
Corresponding Author's Secondary Institution:	
First Author:	Amit Srikant Gharpure, B.D.S, Advanced Education in Restorative Dentistry
First Author Secondary Information:	
Order of Authors:	Amit Srikant Gharpure, B.D.S, Advanced Education in Restorative Dentistry
	Neel B Bhatavadekar, BDS, MS, MPH, Diplomate ABP, ITI Fellow
Order of Authors Secondary Information:	
Abstract:	The recently popularised socket-shield technique involves intentional retention of a section of the remnant root at the time of immediate implant placement to preserve the buccal/proximal bone from resorption. The objective of this systematic review was to assess the literature available on the socket-shield technique and weigh its biological plausibility and long-term clinical prognosis. A Systematic Search was performed in PubMed-Medline, Embase, Web of Knowledge, Google Scholar and Cochrane Central for clinical/ animal studies up to April 2017. 23 studies, consisting of 1 clinical case-control study, 4 animal histological reports, 1 clinical abstract and 17+2* case reports were assessed. 18/23 studies had a duration of less than or up to 12 months. A quality assessment of 5 studies (4 animal histologic and 1 clinical case-control) performed using the modified ARRIVE guidelines revealed that 4/5 studies had low scores. 58/70 (82.86%) implants from 4 animal histological studies had complications; buccal/crestal bone loss (54.55%) and failure of osseointegration (27.27%) were the most common. 33/136 (24.26%) implants from 19+2* clinical studies had complications; buccal/crestal bone loss (78.78%) and shield exposure/failure (12.12%) were the most common. Other complications recorded were, PDL and cementum formation on implant surfaces, pocket formation, inflammation, mucositis and peri-implantitis. However, some clinical reports indicated stable results at 12 months. It would be difficult to predict the long - term success of this technique until high-quality evidence becomes available. *2 studies had both histologic and clinical components which were assessed separately.

Current Evidence on the Socket-Shield Technique: A Systematic Review

Amit S. Gharpure[1], BDS, Advanced Education in Restorative Dentistry*

Neel B. Bhatavadekar[2], BDS, MS, MPH, Diplomate ABP

[1] Currently in Private Practice, Mumbai, India *Former Student, Rutgers School of Dental Medicine, New Jersey, USA

[2] Clarus Dental Specialities, Pune, India. Also, Adjunct Faculty, University of North Carolina at Chapel Hill, North Carolina, USA

Corresponding author:

Amit S. Gharpure, BDS, Advanced Education in Restorative Dentistry
489 Annapurna Mandir,
Adenwala Road, Matunga,
Mumbai 400019, India

Email id – amitsg188@gmail.com
Phone - +919819761255

Conflict of Interest and Source of Funding: There was no support in the form of funding for this study; the authors declare that there was no conflict of interest.

Word Count – 2867
Tables – 4
Figures – 5
References - 49

Short Running Title – A Systematic Review on the Socket-Shield Technique

ABSTRACT:

The recently popularised socket-shield technique involves intentional retention of a section of the remnant root at the time of immediate implant placement to preserve the buccal/proximal bone from resorption. The objective of this systematic review was to assess the literature available on the socket-shield technique and weigh its biological plausibility and long-term clinical prognosis. A Systematic Search was performed in PubMed-Medline, Embase, Web of Knowledge, Google Scholar and Cochrane Central for clinical/ animal studies up to April 2017. 23 studies, consisting of 1 clinical case-control study, 4 animal histological reports, 1 clinical abstract and 17+2* case reports were assessed. 18/23 studies had a duration of less than or up to 12 months. A quality assessment of 5 studies (4 animal histologic and 1 clinical case-control) performed using the modified ARRIVE guidelines revealed that 4/5 studies had low scores. 58/70 (82.86%) implants from 4 animal histological studies had complications; buccal/crestal bone loss (54.55%) and failure of osseointegration (27.27%) were the most common. 33/136 (24.26%) implants from 19+2* clinical studies had complications; buccal/crestal bone loss (78.78%) and shield exposure/failure (12.12%) were the most common. Other complications recorded were, PDL and cementum formation on implant surfaces, pocket formation, inflammation, mucositis and peri-implantitis. However, some clinical reports indicated stable results at 12 months. It would be difficult to predict the long – term success of this technique until high-quality evidence becomes available.

*2 studies had both histologic and clinical components which were assessed separately.

Keywords: Dental Implant, Dental Cementum, Periodontal Ligament, Socket-Shield, Systematic Review, Complications, Adverse effects

INTRODUCTION:

Tooth extractions are followed by multiple dimensional changes in the remnant alveolar bone.[1-5] It has been postulated that retention of the root may alter the physiologic changes seen in extraction sockets.[6] Multiple studies have demonstrated that retaining decoronated roots, either vital or endontically treated, such as the Root Submergence Technique, [7] can preserve the alveolar bone at an extraction site. [8-11]There have also been a few publications which have studied the effect of implants being placed in contact with or in close approximation to retained root pieces which demonstrate the formation of periodontal ligament and/or cementum on implant surfaces.[12-15]

In recent times, there has been an interest in placing implants in close proximity to or in contact with intentionally retained roots to preserve the buccal bone.[6, 16-20] Hurzeler et al. were the first researchers, who described the socket-shield technique, which they claimed, helped preserve the buccal bone after extraction. A buccal root fragment was intentionally retained at the time of extraction as depicted in Figure 1. The root fragment functioned like a shield which preserved the buccal bone from resorption, thereafter an immediate implant was placed palatal to the root fragment. Their histologic study done in an animal model demonstrated the formation of cementum on implant surfaces placed in contact with intentionally retained roots.[6] Using the same principle, other researchers further modified the original technique in order to preserve the proximal bone,[17, 19] and the crestal bone.[21, 22] Another animal histologic study, having a circumferential root fragment design, demonstrated the formation of a fibrous capsule around implants.[23] At present, all clinical human studies currently available on implants placed in close proximity to intentionally retained root fragments using this technique are lower in the hierarchy of evidence as seen in Figure 2. Our aim was to systematically analyse the available literature on this technique, understand its

viability and draw conclusions on its clinical outcome. The primary objective of this systematic review was to answer two fundamental questions -

1) Has the socket-shield technique demonstrated a good long-term prognosis in terms of clinical success?
2) Does this technique, which is used to improve the outcome of implant therapy, especially in the anterior esthetic zone, have sufficient biologic plausibility?

To the best of the authors' knowledge, this was the first systematic review on the socket shield-technique.

MATERIALS AND METHODS:

This systematic review was performed in line with the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement,[24]and the guidelines provided by the Cochrane Handbook for Systematic Reviews were also followed.[25] The focused PICO (population, intervention, control, outcome) question of the present systematic review was 'What is the long-term clinical prognosis and the biologic plausibility of the socket-shield technique used for preservation of buccal/proximal/crestal bone for implant treatment in humans, on the basis of clinical, histologic and radiologic evaluation.' The secondary objectives of the study were to provide a qualitative assessment of the available literature and a statistical distribution of the adverse effects and complications associated with this technique. Initially it was decided to include all randomized control trials. However due to unavailability of clinical trials, cohort studies and systematic reviews, it was decided to include clinical reports as well, although they were lower on the hierarchy of evidence.

Information sources and search protocol

A Systematic Search was performed in PubMed-Medline, Embase, Web of Knowledge, Google Scholar and the Cochrane Central Register of Controlled Trials starting from the year 1970 to April 2017. Figure 3 depicts the search protocol followed. A systematic search was performed, without language restriction, using the search terms 'socket-shield', ' root membrane', 'implant proximity to teeth', 'implant placement in contact with root', 'periodontal ligament formation on implant surface', 'cementum', 'periodontal ligament', 'dental implants' and 'immediate implants' in various combinations with Boolean operators 'AND' and 'OR' with no restrictions set on the document type. The reference lists of published trials, review articles, meta-analyses and case reports/series were also examined to identify other eligible studies. Additionally, high quality peer-review dentistry journals were hand-searched. There were no restrictions placed on the duration of the study and the follow-up.

Inclusion and exclusion criteria

Studies were included if they met the following criteria: (1) RCT, cohort, case-control, case series/report or clinical abstract (2) based on the socket-shield principle, in which implants are placed in close proximity to or in contact with root fragments which are intentionally retained to preserve or promote buccal/proximal/crestal bone. Exclusion criteria were, studies (1) in which root-fragments were not left back intentionally to preserve or promote buccal/proximal/crestal bone and (2) in which implants were unknowingly placed in proximity or in contact with retained roots.

Screening and selection of papers

Both authors assessed the studies, and any conflicts in study selection were resolved by discussion. Studies were assessed on the basis of their title or abstract and those studies which met the inclusion criteria were selected for full text review. The selected papers were then assessed for eligibility (Figure 3).

Assessment of complications and adverse effects

Complications and adverse effects were defined as histologic, clinical or radiologic detrimental effects, which would diminish the success of the implant treatment in the long-term. For animal studies, clinical outcomes assessed were – implant/shield exposure, presence of inflammation, mucositis or peri-implantitis; histologic outcomes assessed were - failure of osseointegration, formation of PDL/cementum on implant surface; radiologic outcomes assessed were buccal/crestal bone loss. For clinical studies, clinical outcomes assessed were – shield (root fragment) exposure, probing pocket depths, deficiency of alveolar ridge; radiologic outcome assessed was buccal/crestal bone loss. Once selected, the studies that met the criteria were analysed for complications and adverse effects as reported by their respective authors. Data tables, histologic images, radiographs and clinical images presented in these studies were also analysed to identify overlooked/missed complications.

Data collection process

Predefined data collection spread sheets were employed for assessment of each publication as shown in Table 1 and consisted of authors' names, year of publication, time of implant placement, loading protocol, complications and adverse effects and duration. Evaluations were carried out independently by both authors and confirmed after comparison.

When in doubt, concerning the extracted data, the corresponding authors were contacted by email for confirmation.

Quality assessment in individual studies

A quality assessment was performed for the animal studies and the human case-control study using a modification of the ARRIVE guidelines specifically designed to assess the quality of experimental research in implant dentistry.[26, 27] Each study was given a score based on various points of the ARRIVE guideline with a maximum score of 28.

Data synthesis for meta-analysis

Heterogeneity of the data was assessed to determine if a meta-analysis could be performed. The level of agreement between the two reviewers regarding relevant factors in the studies was determined using kappa statistics. Data was analysed using SPSS software, (SPSS Statistics for Windows, Version 23.0. IBM Corp, Armonk, NY)

RESULTS:

A total of 498 articles were found after using combinations of various key-words with the initial search strategy. Duplicate articles were removed and titles and abstracts of all articles were screened. Articles in languages other than English such as Dutch, German and Standard Mandarin were translated and those which could not be made available in English (n=2) were discarded. 437 articles were rejected on the basis of their title and abstract. After screening, 42 articles were selected for further analysis. Full texts of the articles were assessed for eligibility. 19 articles were excluded; seven recorded implants placed in impacted teeth, 5 described implant proximity to undetected retained root apices and 4 documented implants placed in contact with intentionally retained root apices without any

intention of bone promotion/ preservation. Out of the 3 studies by Gluckman et al.,[28-30] 2 were literature reviews focused on specific techniques without complete documentation of original cases,[29, 30] and 1 involved pontic shields without clear mention of total number of implants exclusively placed with socket-shield technique,[28] and were excluded.

Study characteristics and outcomes

A total of 23 studies were included in this systematic review. The distribution of the available literature according to its hierarchy is shown in Figure 2. 1 was a case-control study. 4 had animal histologic reports. 2 out of 4 animal histologic studies, [6, 16] were also accompanied by a human case report each. One study was an abstract documenting 23 original cases.[31] The remaining 17 articles were clinical human case reports and case series. The details of the studies are provided in Table 1. The frequencies and percentages of the complications and adverse effects were calculated and are listed in Table 2, Table 3, Figure 4 and Figure 5.

Quality assessment in individual studies

A quality assessment based on the modified ARRIVE guidelines specifically designed for experimental research in implant dentistry,[26, 27] was performed on 4 animal studies and 1 case-control study and their scores out of a total of 28 can be seen in Table 4. The remaining studies were case-reports or case-series and they were ineligible for a quality assessment.

Data synthesis for meta-analysis

A meta-analysis could not be performed due absence of homogeneity among the studies and the lack of well-designed randomized controlled trials. However, a percentage-wise statistical distribution of complications and adverse effects was performed (Table 2 and

Table 3). Kappa statistics showed a high level of agreement between the reviewers (K > 0.80).

DISCUSSION:

Parlar et al. were the first to place 18 implants in the centre of prepared hollow chambers of decoronated roots having slits at the periphery in nine mongrel dogs (Table 1).[23] Four months later, histological examination of the specimens showed newly formed periodontal ligament, alveolar bone, and root cementum in the space between the implant and the wall of the dentin chamber. A fibrous capsule covered their surfaces and they failed to osseointegrate with cellular cementum deposition on 2 implants and 1mplant exposure.[23] Hurzeler et al. intentionally left a buccal portion of the remnant root coated with enamel matrix derivative (EMD; Emdogain, Straumann), to preserve the buccal cortical plate from resorption during an immediate implant placement (Figure 1).[6] They were the first to name this technique as 'socket-shield'. Histological examination of 4 implants placed in a beagle dog demonstrated cementum formation on implant surface where a direct root-implant contact was noted. When the implant and the root piece were in close proximity with no surface contact, a 0.5 mm connective tissue band was found between the implant and the buccal root piece. They also presented a clinical case report using this technique wherein the implant was immediately loaded and followed up for 6 months (Table 1). Baumer et al. further investigated this technique by employing a similar study design but with a larger sample size (Table 1).[16] Their histologic evaluation showed osseointegration and bone formation between the fragments and the implants after 4 months of healing. They also presented a clinical case report (Table 1). The histologic study by Guirado et al.,[21] compared the effects of varying thickness of the socket-shield and the buccal alveolar bone on the success of this technique. Irrespective of the thickness of the socket-shield and bone used,

there was a rapid crestal bone loss noted at 4 months, ranging from 3.13 ± 0.54 mm to 6.01 ± 2.23 mm.

The duration of all four histologic studies was only 4 months. As seen in Table 3 and Figure 4, the implants demonstrated complications such as crestal bone loss (54.55%),[21] failure to osseointegrate (27.27%),[23] formation of PDL (3.03%),[6] and cementum (6.06%),[6, 16] on their surface. Another important factor which needs to be considered is the quality of the animal studies. Scores of the modified ARRIVE quality assessment scale for 3 out of 4 studies,[6, 16, 23] were 15, 15 and 16 out of a total score of 28 respectively (Table 4), which was well below the average of 19.35 ± 3.78 out of 28 reported in implant studies carried out in dogs.[27] These low scores may further undermine the findings of the studies. Thus, the current histologic evidence is insufficient to support the biologic plausibility of this technique.

The only case-control study on the socket-shield was published by Abadzhiev et al. and its details are described in Table 1. [32] Though the socket-shield group had better results in terms of bone loss, esthetics and soft tissue volume, a mean bone loss of 0.8mm (2%) was noted at 24 months [32]. However, it had a score of 4 out of a total score of 28 (Table 4) on the modified ARRIVE quality assessment scale[25,26], which is extremely low as compared to mean score of 19.2 ± 2.58 out of 28 seen in other clinical implant studies.[27] Such a low score may undermine the results of this study and reduce the generalizability and external validity of its findings. Description of the various case series and reports based on the socket-shield technique and their complications can be seen in Table 1. A majority of the case reports documented this technique for single implant restorations in the anterior esthetic region, [33-38] and involved immediate implant placement at the time of preparation of the socket-shields. Some clinicians made modifications to the original technique in terms of time of implant placement, [20] and location of the shield,[17, 22] but followed the same principle.

As seen in Table 1, 13 case reports and abstracts published the findings of only 1 patient each. [6, 16, 17, 19, 33-41]. Thus, a possibility of a case selection bias cannot be ruled out, wherein the authors might have presented only those cases which had successful outcomes. 16 clinical human studies show short-term follow-ups of less than or up to 12 months (Table 1).[6, 16, 17, 19, 20, 22, 31, 33-37, 39-42] Such short periods are insufficient to effectively demonstrate the failures and complications of this technique. Thus, there is a high possibility that the number of complications, adverse effects and failures is under-reported. What also needs to be considered is that publications by certain groups of authors,[18, 43] showed very good long-term results whereas few other publications,[21-23] had a high number of complications and adverse effects. This probably indicates that the socket-shield procedure might be technique sensitive.

There have been multiple studies in the past which have documented the fate of root pieces left after undetected root fractures at the time of extraction.[44-46] One clinical human study documented that 16.2% fractured root pieces in a sample size of 2000 became symptomatic.[45] In another study, histologic evaluation of fractured root pieces left back during extraction revealed that 27% of them had pathologies such as sinus tracks, inflammation and cysts.[46] Also, the root pieces showed signs of continuous resorption and repair with acellular cementum formation.[46] More recently, complications of infection and bone loss were also demonstrated when implants were placed in contact with unnoticed retained root pieces at the time of extraction.[47, 48] The clinical studies in this review presented with several types of complications and adverse effects such as crestal/buccal bone loss (most common with 78.78% of all reported complications), exposure of the shield and deep probing pockets (Table 3 and Figure 5). Thus, there is a possibility that the socket-shield may pose a risk of infection to implants placed in close proximity. Further, there is a possibility that loss of the socket-shield either by resorption or due to extraction following infection , may lead to loss of the bone it preserves and may predispose the implant surface to exposure.

This systematic review has its share of limitations. Although a variety of search terms have been used for this technique and sincere efforts were made to review all available literature on the subject, it possible to have missed certain articles describing the same technique but with a different name. Also, certain studies which could not be translated into English were not included in the study. All the clinical studies discussed (expect Abadzhiev et al.[32]) are case-reports, each with their own sets of methodologies and parameters for assessment making comparisons of outcomes difficult. As a result only 5 studies could be included for the modified ARRIVE quality analysis (Table 4). Also, there is a possibility of an underestimation of the actual complications due to possible operator bias in the individual reports which could not be assessed. It must be noted that this paper has provided only a descriptive assessment of the cases and is limited in the interpretation of the results, determination of prognosis and extrapolation of the findings

CONCLUSION:

After going through the available literature, the overall evidence in support of the socket-shield technique seems limited at the moment. The present histologic evidence indicates rapid bone loss, failure of osseointegration, formation of cementum, PDL or PDL like fibrous tissue on implant surfaces in proximity to the shield and weakens the biologic plausibility of this technique. Case-reports with short follow-ups are insufficient to determine the long-term clinical prognosis of this socket-shield technique. More studies which are higher on the hierarchy of evidence such as RCTs, well-designed prospective cohorts are required to fully establish the biologic plausibility and clinical success of this technique.

CONFLICT OF INTEREST:

The authors declare that there was no conflict of interest for this study. This study did not receive any funding.

Bibliography

1. Amler MH, Johnson PL, Salman I. Histological and histochemical investigation of human alveolar socket healing in undisturbed extraction wounds. *J Am Dent Assoc.* 1960;61:32-44.
2. Araujo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. *J Clin Periodontol.* 2005;32(2):212-218.
3. Fickl S, Zuhr O, Wachtel H, Stappert CF, Stein JM, Hurzeler MB. Dimensional changes of the alveolar ridge contour after different socket preservation techniques. *J Clin Periodontol.* 2008;35(10):906-913.
4. Pietrokovski J, Massler M. Alveolar ridge resorption following tooth extraction. *J Prosthet Dent.* 1967;17(1):21-27.
5. Schropp L, Wenzel A, Kostopoulos L, Karring T. Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study. *Int J Periodontics Restorative Dent.* 2003;23(4):313-323.
6. Hurzeler MB, Zuhr O, Schupbach P, Rebele SF, Emmanouilidis N, Fickl S. The socket-shield technique: a proof-of-principle report. *J Clin Periodontol.* 2010;37(9):855-862.
7. Salama M, Ishikawa T, Salama H, Funato A, Garber D. Advantages of the root submergence technique for pontic site development in esthetic implant therapy. *Int J Periodontics Restorative Dent.* 2007;27(6):521-527.
8. Filippi A, Pohl Y, von Arx T. Decoronation of an ankylosed tooth for preservation of alveolar bone prior to implant placement. *Dent Traumatol.* 2001;17(2):93-95.
9. Andersson L, Emami-Kristiansen Z, Hogstrom J. Single-tooth implant treatment in the anterior region of the maxilla for treatment of tooth loss after trauma: a retrospective clinical and interview study. *Dent Traumatol.* 2003;19(3):126-131.
10. Sapir S, Shapira J. Decoronation for the management of an ankylosed young permanent tooth. *Dent Traumatol.* 2008;24(1):131-135.
11. Malmgren B. Decoronation: how, why, and when? *J Calif Dent Assoc.* 2000;28(11):846-854.
12. Buser D, Warrer K, Karring T. Formation of a periodontal ligament around titanium implants. *J Periodontol.* 1990;61(9):597-601.
13. Warrer K, Karring T, Gotfredsen K. Periodontal ligament formation around different types of dental titanium implants. I. The self-tapping screw type implant system. *J Periodontol.* 1993;64(1):29-34.
14. Gray JL, Vernino AR. The interface between retained roots and dental implants: a histologic study in baboons. *J Periodontol.* 2004;75(8):1102-1106.
15. Jahangiri L, Hessamfar R, Ricci JL. Partial generation of periodontal ligament on endosseous dental implants in dogs. *Clin Oral Implants Res.* 2005;16(4):396-401.
16. Baumer D, Zuhr O, Rebele S, Schneider D, Schupbach P, Hurzeler M. The socket-shield technique: first histological, clinical, and volumetrical observations after separation of the buccal tooth segment - a pilot study. *Clin Implant Dent Relat Res.* 2015;17(1):71-82.
17. Kan JY, Rungcharassaeng K. Proximal socket shield for interimplant papilla preservation in the esthetic zone. *Int J Periodontics Restorative Dent.* 2013;33(1):e24-31.
18. Siormpas KD, Mitsias ME, Kontsiotou-Siormpa E, Garber D, Kotsakis GA. Immediate implant placement in the esthetic zone utilizing the "root-membrane" technique: clinical results up to 5 years postloading. *Int J Oral Maxillofac Implants.* 2014;29(6):1397-1405.
19. Cherel F, Etienne D. Papilla preservation between two implants: a modified socket-shield technique to maintain the scalloped anatomy? A case report. *Quintessence Int.* 2014;45(1):23-30.
20. Glocker M, Attin T, Schmidlin PR. Ridge Preservation with Modified “Socket-Shield” Technique: A Methodological Case Series. *Dent J.* 2014;2(1):11-21.
21. Guirado JL, Troiano M, Lopez-Lopez PJ, et al. Different configuration of socket shield technique in peri-implant bone preservation: An experimental study in dog mandible. *Ann Anat.* 2016;208:109-115.

22. Troiano M, Benincasa M, Sánchez P, Calvo-Guirado J. Bundle bone preservation with Root-T-Belt: Case study. *Ann Oral Maxillofac Surg.* 2014;2(1):7.
23. Parlar A, Bosshardt DD, Unsal B, Cetiner D, Haytac C, Lang NP. New formation of periodontal tissues around titanium implants in a novel dentin chamber model. *Clin Oral Implants Res.* 2005;16(3):259-267.
24. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *The BMJ.* 2009;339:b2535.
25. Higgins JPT, Green S (editors). Cochrane handbook for systematic reviews of interventions Version 5.1.0 [updated March 2011]. The Cochrane Collaboration, 2011. Available from www.handbook.cochrane.org.
26. Kilkenny C, Browne W, Cuthill IC, Emerson M, Altman DG. Animal research: reporting in vivo experiments: the ARRIVE guidelines. *J Gene Med.* 2010;12(7):561-563.
27. Vignoletti F, Abrahamsson I. Quality of reporting of experimental research in implant dentistry. Critical aspects in design, outcome assessment and model validation. *J Clin Periodontol.* 2012;39 Suppl 12:6-27.
28. Gluckman H, Du Toit J, Salama M. The Pontic-Shield: Partial Extraction Therapy for Ridge Preservation and Pontic Site Development. *Int J Periodontics Restorative Dent.* 2016;36(3):417-423.
29. Gluckman H, Salama M, Du Toit J. Partial Extraction Therapies (PET) Part 1: Maintaining Alveolar Ridge Contour at Pontic and Immediate Implant Sites. *Int J Periodontics Restorative Dent.* 2016;36(5):681-687.
30. Gluckman H, Salama M, Du Toit J. Partial Extraction Therapies (PET) Part 2: Procedures and Technical Aspects. *Int J Periodontics Restorative Dent.* 2017;37(3):377-385.
31. Implant Insertion After Tooth Extraction: Clinical Outcomes with Different Approaches (Including Socket Preservation, Immediate, Early and Delayed Placement). *Clin Oral Implants Res.* 2016;27:530.
32. Abadzhiev M, Nenkov P, Velcheva P. Conventional immediate implant placement and immediate placement with socket-shield technique – Which is better. *Int J Clin Med Res.* 2014;1(5):176-180.
33. Chen C, Pan Y. Socket Shield Technique for Ridge Preservation: A Case Report. *J Prosthodont Implantol.* 2013;2(2):16-21.
34. Gluckman H, Du Toit J, Salama M. The socket-shield technique to support the buccofacial tissues at immediate implant placement. *Int Dent Afr Ed.* 2015;5(3):6-14.
35. Al Dary H, Al Hadidi A. The Socket Shield Technique using Bone Trephine: A Case Report. *Int J Dent Oral Sci.* 2015;5(001):1-5.
36. Wadhwani P, Goyal S, Tiwari S, Syed S, Paul T, Komal A. Socket Shield Technique: A New Concept of Ridge Preservation. *Asian J Oral Health Allied Sci.* 2015;5(2):55-58.
37. Holbrook SE. Model-Guided Flapless Immediate Implant Placement and Provisionalization in the Esthetic Zone Utilizing a Nanostructured Titanium Implant: A Case Report. *J Oral Implantol.* 2016;42(1):98-103.
38. Mitsias ME, Siormpas KD, Kontsiotou-Siormpa E, Prasad H, Garber D, Kotsakis GA. A Step-by-Step Description of PDL-Mediated Ridge Preservation for Immediate Implant Rehabilitation in the Esthetic Region. *Int J Periodontics Restorative Dent.* 2015;35(6):835-841.
39. Al Dary H. Socket Shield Technique with and without Implant Placement to Maintain Pink Aesthetics : Case Report. *Smile Dent J.* 2016;11:16-20.
40. Huang H, Shu L, Liu Y, Wang L, Li J, Fu G. Immediate implants combined with modified socket-shield technique: A Case Letter. *J Oral Implantol.* 2017.
41. Saeidi Pour R, Zuhr O, Hürzeler M, et al. Clinical Benefits of the Immediate Implant Socket Shield Technique. *J Esthet Restor Dent.* 2017:n/a-n/a.
42. Chen W-C, Chen C-l. A Preliminary Clinical Study of Buccal Bone Alteration Using the Socket-Shield Technique and Immediate Implant Placement. *J Taiwan Acad Periodontol.* 2016;21(2):137-145.

43. Bäumer D, Zuhr O, Rebele S, Hürzeler M. Socket Shield Technique for immediate implant placement – clinical, radiographic and volumetric data after 5 years. *Clin Oral Implants Res.* 2017:n/a-n/a.
44. Nayyar J, Clarke M, O'Sullivan M, Stassen LF. Fractured root tips during dental extractions and retained root fragments. A clinical dilemma? *Br Dent J.* 2015;218(5):285-290.
45. Helsham RW. Some observations on the subject of roots of teeth retained in the jaws as a result of incomplete exodontia*. *Aust Dent J.* 1960;5(2):70-77.
46. Herd JR. The retained tooth root. *Aust Dent J.* 1973;18(3):125-131.
47. Guarnieri R, Giardino L, Crespi R, Romagnoli R. Cementum formation around a titanium implant: a case report. *Int J Oral Maxillofac Implants.* 2002;17(5):729-732.
48. Langer L, Langer B, Salem D. Unintentional root fragment retention in proximity to dental implants: a series of six human case reports. *Int J Periodontics Restorative Dent.* 2015;35(3):305-313.
49. Lagas LJ, Pepplinkhuizen JJFAA, Bergé SJ, Meijer GJ. Implant placement in the aesthetic zone: the socket-shield-technique. *Ned Tijdschr Tandheelkd.* 2015;122(1):33-36.

423 Table 1: Details of the all the histologic and animal studies on the socket-shield technique
424 along with a description of their complications and adverse effects

Sr. No	Study Authors and Year of Publication	Sample size	Time of Implant placement	Implant Loading Protocol	Complications and Adverse Effects	Duration of the Study
Histologic Studies						
1.	Parlar et al. 2005[23]	9 mongrel dogs 18 implants	Immediate	N/A	Fibrous tissue around all implants, failure to osseointegrate 2 implant surfaces - cementum formation 1 implant exposure 2 sites inflammation	4 months
2.	*Hurzeler et al. 2010[6]	1 beagle dog, 4 implants	Immediate	N/A	2 implants surfaces - cementum formation, 2 implant surfaces – ^PDL formation	4 months
3.	#Baumer et al. 2015[16]	3 beagle dogs 12 implants	Immediate	N/A	None	4 months
4.	Guirado et al. 2016[21]	6 American Foxhound dogs 36 implants	Immediate	N/A	3 implants- mucositis and peri-implantitis. Mean crestal bone loss ranging from 3.13 ± 0.54 mm to 6.01 ± 2.23 mm Small fractures in some cases showed resorptive process	4 months
Clinical Studies						
-	*Hurzeler et al. 2010[6]	1 patient 1 implant	Immediate	Immediate	None	6 months
-	#Baumer et al. 2015[16]	1 patient 1 implant	Immediate	Delayed,6 months	Mean buccal bone loss of 0.88 mm Range - 1.67 mm to 0.15 mm.	6 months
5.	Abadzhiev et al. 2014[32] (case-control study)	25 patients, 26 implants (10 implants with shields)	Immediate	Not specified	Mean crestal bone loss of 0.8 mm	24 months
6.	Kan and Rungcharassaeng 2013[17]	1 patient 1 implant	Immediate	Immediate	None	12 months
7.	Chen and Pan 2013[33]	1 patient 1 implant	Immediate	Delayed,4 months	Mean buccal bone loss of 0.72mm	12 months
8.	Cherel and Etienne 2014[19]	1 patient 2 implants	Immediate	Immediate	Coronal part of root fragment visible through mucosal bed after removal of temporary crowns	11 months
9.	Siormpas et al. 2014[18]	46 patients 46 implants	Immediate	Immediate	Mean crestal bone loss of 0.18±0.09 mm on mesial and 0.21±0.09 mm on palatal† 1 case of apical root resorption of socket shield	24-60 months (median 40)
10.	Glocker et al. 2014[20]	3 patients 3 implants	Delayed, 6 months	Not specified	None	6months
11.	Troiano et al. 2014[22]	7 patients 10 implants	Immediate	Delayed, 3 months	Mean crestal bone loss 1.3 ±0.2 mm	6 months
12.	Gluckman et al. 2015[34]	1 patient 1 implant	Immediate	Immediate	None	12 months
13.	Al Dary and Al Hadadi 2015[35]	1patient 1implant	Immediate	Immediate	None	5 months
14.	Wadhwani et al. 2015[36]	1patient 1implant	Immediate	Delayed,4 months	None	4 months
15.	Lagas et al. 2015[49]	16 patients 16 implants	Immediate	10/16 Immediate.	1 shield failed due to infection, 1 case showed deficiency of alveolar ridge	0.50 - 2.85 years
16.	Mitsias et al. 2015[38]	1 patient 1 implant	Immediate	Immediate	Up to 4mm probing pocket around implant at 3 months†	36 months
17.	Holbrook 2016[37]	1 patient 1 implant	Immediate	Immediate	None	12 months
18.	Chen and Chen 2016[42]	4 patients 4 implants	Immediate	Not specified	Mean buccal bone loss of 0.83 ± 0.178 mm	3 months
19.	Abitbol et al. 2016[31]	20 patients 23 implants	Immediate	Immediate	probing pocket of 8 mm in the mesio-buccal part of one shield, 1 shield exposure	12 months
20.	Al Dary 2016[39]	1 patient, 1implant	Immediate	Delayed	None	3 months
21.	Hong Huang et al. 2017[40]	1 patient 1 implant	Immediate	Delayed, 6 months	None	12 months
22.	Saeidi Pour et al. 2017[41]	1 patient 1 implant	Immediate	Immediate	None	3 months
23.	Baumer et al. 2017[43]	10 patients 10 implants	Immediate	Immediate 4/10,Delayed 6/10	None	51 to 63 months (mean 58)

*,# these studies had a histological and clinical component and are repeated in both sections ^PDL indicates periodontal ligament †not included in statistical analysis due to an absence of consensus in the literature on acceptable values

Table 2: A quantitative description of the total sample size, number of studies and total complications and adverse effects associated with the implants and root pieces in the socket-shield technique

Type and Number of Studies	Total Cases	Total Complications and Adverse Effects
Histological Studies (n=4)	19 dogs, 70 socket-shields with 70 implants	58 (82.86%) Implants
Clinical Studies (n=19+2*)	144 patients, 136 socket-shields with 136 Implants	33 (24.26%) Implants
*Two studies had clinical and histologic components and are included in both groups # did not include cases where the total implant number was not specified		

Table 3: Frequency and percentage distribution of the complications and adverse effects of the socket-shield technique

Nature of Complications/ Adverse Effects	No. of Reported Cases
Histologic Studies	
1. Mean crestal bone loss from 3.13 ± 0.54 mm to 6.01 ± 2.23 mm at 4 months[21]	36 (54.55%)
2. Failure of osseointegration due to fibrous healing[23]	18 (27.27%)
3. Inflammation, Mucositis and Peri-implantitis[21, 23]	5 (7.58%)
4.Cementum like hard tissue formation[6, 23]	4 (6.06%)
5. *PDL-like tissue formation on implant surface[6]	2 (3.03%)
6. Implant Exposure[23]	1 (1.52%)
Total no of complications	66 (100%)
Total documented implants with complications/undesired outcomes in histologic studies	58
Clinical Studies	
1. Mean bone loss around implants (Total Cases)	26 (78.78%)
Crestal loss of 1.3 ± 0.2 mm at 6 months[22]	10
Buccal loss of 0.88 mm at 6 months[16]	1
Buccal loss of 0.83 ± 0.178 mm at 3 months[42]	4
Crestal loss of 0.8mm at 24 months[32]	10
Buccal loss of 0.72 mm at 12 months[33]	1
2. Shield exposure/failure (Total Cases)	5 (15.15%)
shield failure due to infection[49]	1
coronal part of shield exposed on mucosal bed at 3-4 months[19]	2
shield exposure at 12 months[31]	1
apical root resorption[18]	1
3. Probing depths (Total Cases)	1 (3.03%)
8 mm at 12 months[31]	1
4. Deficiency of alveolar ridge[49]	1 (3.03%)
Total documented implants with complications/undesired outcomes in clinical studies	33 (100%)
*PDL indicates periodontal ligament	

Table 4: A quality analysis of the animal studies and human case-control study according to the modified ARRIVE guidelines for assessing quality in implant research (Vignoletti and Abrahamsson, 2012). Scores were assessed for each point and a total score was calculated.

Number	Score Range	Item Name	Parlar et al. 2005[23]	Hurzeler et al. 2010[6]	Baumer et al. 2015[16]	Guirado et al. 2016[21]	Abadzhiev et al. 2014[32]
1	0-2	Title	1	1	1	1	1
2	0-2	Abstract	1	1	1	1	0
3	0-2	Introduction and Background	1	1	1	1	0
4	0-1	Objectives	1	1	1	1	0
5	0-1	Methods Ethics Statement	0	1	1	1	0
6 a	0-1	Study Design	1	1	1	1	1
6 b	0-1		0	0	0	1	0
7 a	0-1	Experimental Procedures	1	1	1	1	0
7 b	0-1		1	1	1	1	N/A
7 c	0-1		1	1	1	1	0
8	0-1	Experimental Animals/ Subjects	1	1	1	1	1
9	0-1	Housing and Husbandry /Dental History	0	0	0	1	0
10 a	0-1	Sample Size	1	1	1	1	1
10 b	0-1		0	0	0	0	0
11	0-1	Experimental Outcomes	1	1	1	1	0
12 a	0-1	Statistical Methods	N/A	N/A	N/A	1	0
12 b	0-1		N/A	N/A	N/A	1	0
12 c	0-1		N/A	N/A	N/A	0	0
13	0-1	Results, Numbers analysed	1	1	1	1	0
14	0-1	Outcomes and Estimation	N/A	N/A	N/A	1	0
15	0-1	Adverse Effects	1	0	0	0	0
16	0-2	Discussion/Interpretation	1	1	1	1	0
17	0-1	Generalizability/Translation	0	0	1	0	0
18	0-1	Funding	1	1	1	1	0
	0-28	Total Score	15	15	16	20	4

Figure 1: Diagrammatic representation of the socket-shield technique: The black arrow indicates the root fragment retained to serve as a ‘socket-shield’ to prevent resorption of buccal bone. Placement of implant is palatal/lingual to this root fragment.

Figure 2: Schematic representation of the search protocol used for the selection of studies used in the systematic review.

Figure 3: Distribution of available literature according to the hierarchy of evidence.

Figure 4: Graphical representation of the distribution of complications/ adverse effects in the histologic studies on the socket-shield technique included in this review.

Figure 5: Graphical representation of the distribution of the complications/adverse effects in the clinical studies on the socket-shield technique included in this review.

Figure 1

Click here to download Figure Figure 1.jpg

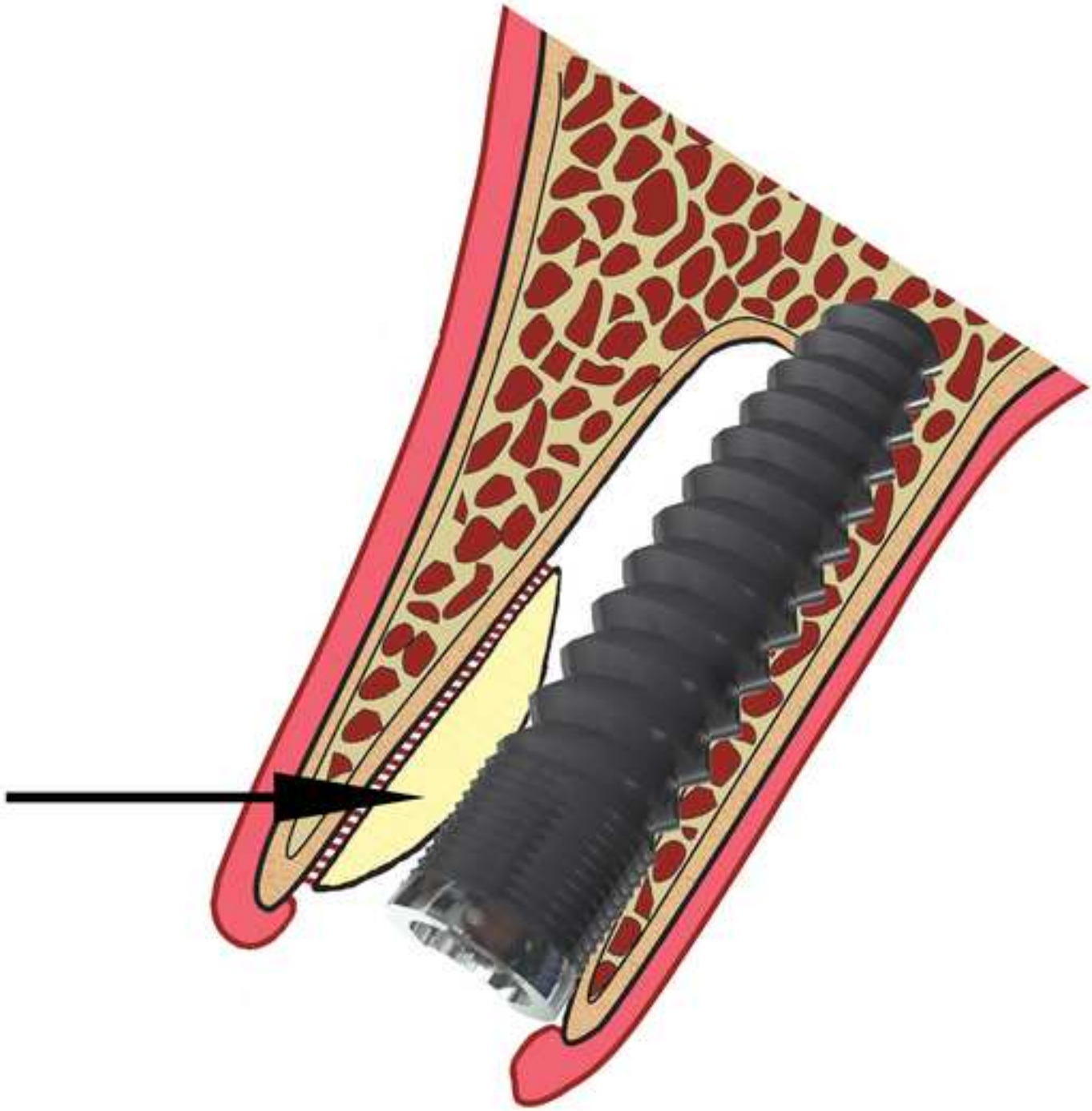

Figure 2

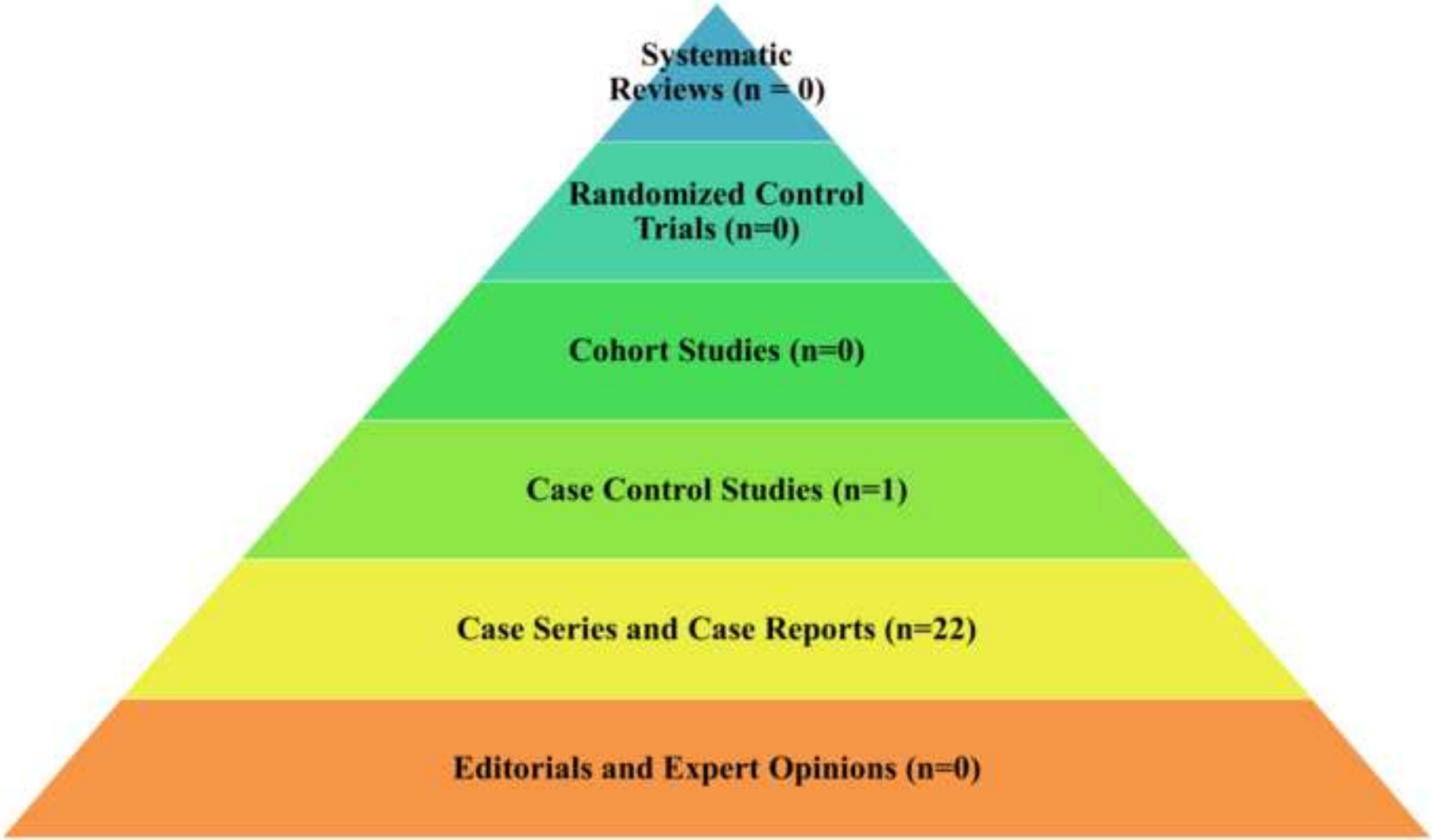

Figure 3

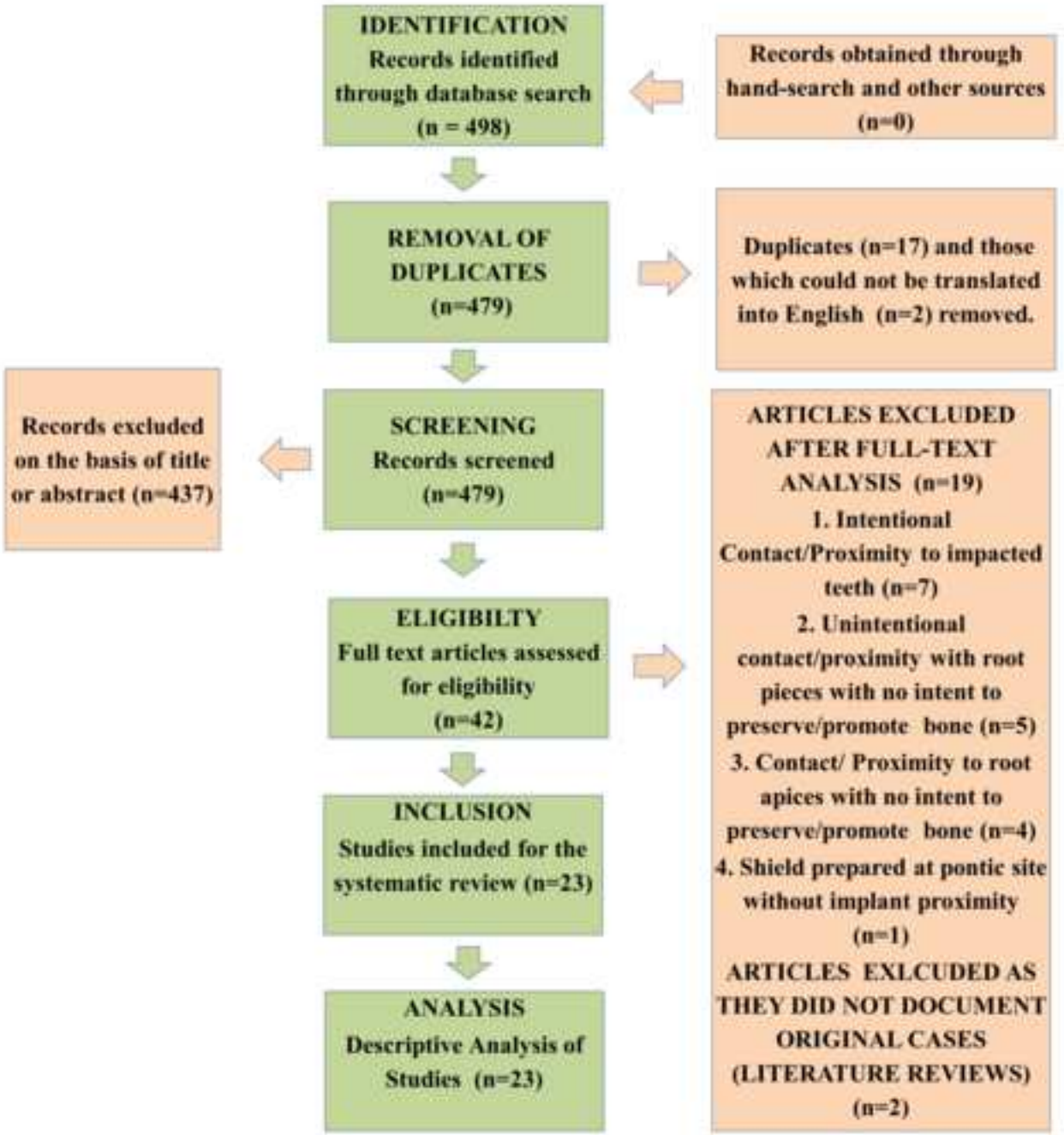

Figure 4

Click here to download Figure Figure4_final.tif

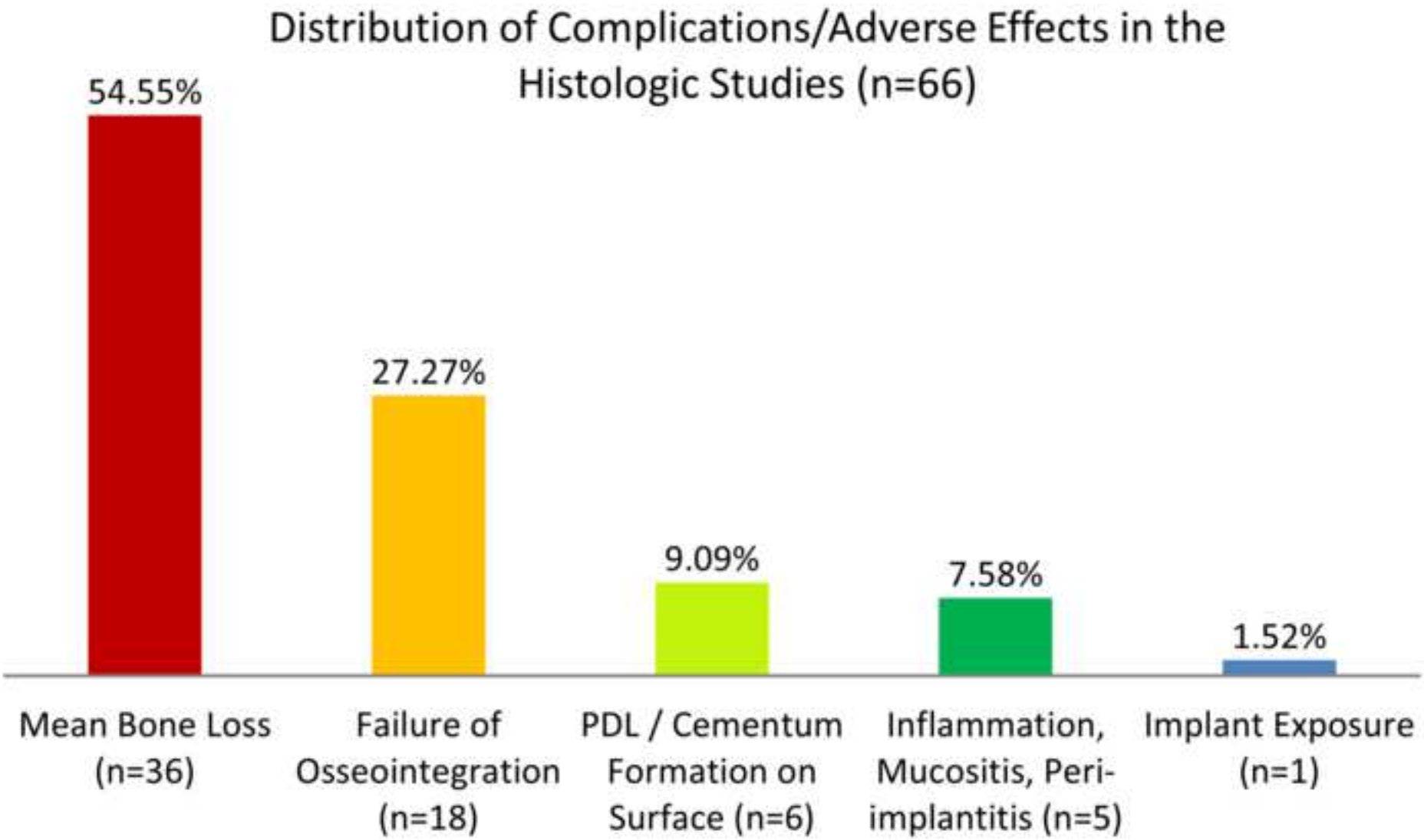

Figure 5

Click here to download Figure Figure5_final.tif