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LITERATURE REVIEW

Endodontic complications associated with orthodontic temporary anchorage devices: A systematic review of human studies

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Abstract

This review, registered in PROSPERO (CRD42018102582), assessed the effect of temporary anchorage device placement on endodontic complications. A search strategy was followed to identify studies where any temporary anchorage devices contacted or were in proximity to tooth roots in humans. Studies with low possibility of bias and published in English or Latin-character languages were considered for inclusion. Ten studies were identified; five case reports, one clinical study and four studies with intentional injury, totalling 736 temporary anchorage devices in 327 patients. Complications may ensue following temporary anchorage device placement, whether or not root contact occurs. Chronic apical periodontitis developed when there was root injury involving the pulp; necrosis can also occur. When damage was limited to the periodontal ligament, cementum or dentine, repair occurred, normally within 12 weeks. Clinicians should be aware of the potential for endodontic complications during temporary anchorage device placement, as well as during orthodontic treatment.

Introduction

Temporary anchorage devices (TADs), also known as miniscrews or orthodontic mini-implants, consist of small screws placed in the maxillary bone to aid in orthodontic anchorage processes *ad interim*. Their diameters range from 1.2 to 2 mm and they are commonly available in lengths of 6, 8 and 10 mm (1). TADs are used as an alternative to improve traditional means of anchorage, being a substitute to the use of teeth, extra- or intra-oral appliances. Thus, their use aims to avoid encountering undesirable effects such as unwanted movement of the anchorage unit or limitations in treatment, such as an absence of an anchorage unit (2–4). Further favourable characteristics of TADs include good success rates, low cost and easy implantation (5). TADs are an effective alternative to Nance palatal arches and extra-oral headgear for supplementing anchorage (6,7). TADs can also be loaded immediately (3,8), and their effectiveness does not directly depend on patient co-operation, as is the case with extra-oral anchorage devices (2).

On account of their small size, TADs can be implanted in several intra-oral regions such as the zygomatic process, the palate, anterior nasal spine, between the roots of teeth, the retromolar region, mandibular ramus and body, and lateral to the maxillary sinus (9). Their placement is often in close proximity to the roots of teeth, the periodontal ligament (PDL) and nerve branches, rendering these sites at increased risk of iatrogenic damage (10,11), with the potential for short- or long-term endodontic, and/or periodontal complications. Therefore, it is important that clinicians placing TADs are aware of these risks in order to prevent, or diagnose and manage such potential complications appropriately. Considering that the development of complications may lead to changes in

a previously consented orthodontic treatment plan, referral to specialists, or both, general dentists and specialist orthodontists should discuss the possible risks and complications associated with TADs with their patients, as well as propose alternative options, as part of the process of shared decision-making and informed consent (12,13).

The literature assessing TADs-related endodontic complications is scarce. One previous systematic review assessed root damage as a result of TAD root contact (14). A second study that included mostly animal studies assessed the effect of TADs contacting roots and surrounding structures (15). To the best of our knowledge, no previous review has specifically focused on the *in vivo* effect of TAD placement on endodontic complications. Therefore, the aim of our study was to assess the effect of TAD placement, on endodontic complications, through a systematic review.

Materials and methods

Protocol and registration

The systematic review protocol was registered *a priori* in the International Prospective Register of Systematic Reviews under CRD42018102582. The review followed the Joanna Briggs Institute (JBI) methodology guidelines for a systematic review of association (aetiology) (16). The review was conducted and reported in strict accordance with PRISMA guidelines for reporting systematic reviews and meta-analyses (17).

Review question

The objective of this review was to identify the association of TADs on the development of endodontic complications. The following specific research question was addressed: What is the effect of TADs usage on developing endodontic complications?

Inclusion criteria

As this systematic review was focused on aetiology and risk, the research question was generated based on population, exposure and outcome (PEO)(16):

Population: studies of healthy human participants in any dentition, who had placement of one or more TADs. There were no restrictions on the basis of age or sex.

Exposure: any type or number of TADs that contacted or were in proximity to a dental root. This was diagnosed radiographically, or after extraction of the affected tooth using either visual assessment, histological or microscopic examination.

Outcome: specific outcomes related to endodontic complications that were assessed: loss of pulpal sensibility (assessed with dental pulp testing), pulpal necrosis, apical periodontitis and root damage (assessed by radiographic imaging, histological and/or microscopic examination).

Study design: case reports, observational studies, randomised and non-randomised clinical trials were considered for inclusion.

Search strategy

A 3-step search strategy was adopted. An initial limited search of MEDLINE (via Ovid) and Scopus databases was performed to identify keyword and index terms pertinent to the research question. The search strategy (Table S1) was then developed using all identified keywords and index terms, and applied to the following electronic databases: MEDLINE (via Ovid), Embase, Scopus, and Dentistry and Oral Sciences Source (DOSS) (EBSCO) from inception date to 23 March 2019. Only publications in English or languages with Latin characters were included. Citation search of reference lists of all included articles was also performed. There were no restrictions placed on the year of publication. After removal of duplicate records, two reviewers (GM, GJF) independently and in duplicate screened the titles and abstracts of the articles in order to distinguish potentially relevant studies for inclusion.

Assessment of methodological validity and possibility of bias

After retrieval of the full-text articles of the potentially relevant studies, the same reviewers independently assessed these studies for inclusion using standardised study design-specific critical appraisal tools available from the JBI (18,19). Since the review aimed to synthesise the best available evidence, only those studies having high methodological quality (a score > 70%) were included. Authors were contacted if any questions from the critical appraisal tools were scored as 'unclear'. Any disagreements that arose were resolved through discussion with the first author, who is a JBI trained and accredited reviewer.

Data extraction

Data were extracted from the included studies, independently, by the two reviewers using a customised data collection sheet. Data included author names, year of publication, study setting, study design, number of participants, exposures and outcomes of importance to the review question. Authors of included studies were

contacted for clarification or to request additional information relevant to the review that was missing from their published articles.

Data synthesis

Following tabulation, findings were described in a narrative synthesis.

Results

Search strategy results

This review identified 6243 articles. After screening and full-text assessment, a total of 10 studies were included. Citation search of the included articles did not reveal additional records. Figure 1 shows the flow chart for the selection of the studies included in the systematic review according to the PRISMA guidelines (17). Characteristics of the excluded studies in the eligibility phase are presented in Table S2.

Methodological validity and possibility of bias

As all studies scored > 70%, they were included in the systematic review (Table S3).

Included studies

Table 1 shows the main characteristics of the included studies; all were published in English (20–29). There were 327 participants with 736 TADs. One case report was part of a previously published study; however, a separate analysis was undertaken in the latter (25,27). Authors of a single study were contacted and replied to requests for clarification (28). In 39 subjects, TAD placement was carried out aiming to cause intentional injury of teeth planned for extraction as part of the orthodontic treatment plan (20,21,25,27,29). There was a single retrospective clinical study that contributed with approximately 86% of the cases (28), and five case reports (22–24,26,27). Seven patients required treatment as a consequence of TAD-related sequelae.

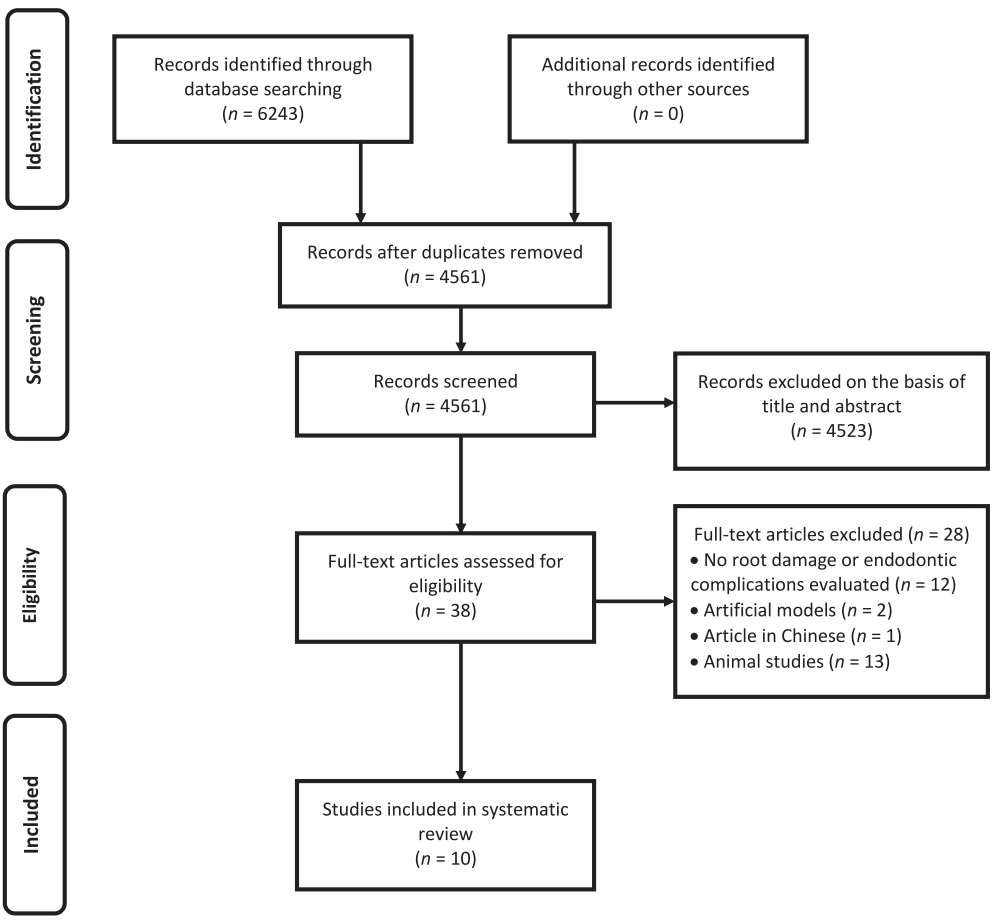

Fig. 1 Flow chart of the screening and study selection process.

Table 1 Characteristics of included studies

Author	Country	Participants	Number TAD used	Diameter x length of TAD (mm)	Number roots contacted	Teeth with pulp contact	TAD contact/use	Follow-up period	Clinical findings	Overall conclusions
Case reports										
Lim *et al*. (22)	Korea	1	2 (replaced 6 times)	1.8 × 7.0	1	0	2.5 years	2 years	Late occurrence of pain, slight tenderness to percussion and palpation of the related soft tissues, negative response to pulp sensibility testing, radiolucent lesion	• TADs placement can cause chronic apical periodontitis • Root canal treatment followed by surgery, when required, will lead to healing
Er *et al*. (23)	Turkey	1	2	1.5 × 10.0	1	0	2 months, 2 weeks	10 months	Pain, sinus tracts, radiolucent lesion, no tenderness to percussion, negative response to pulp sensitivity testing	
Hwang *et al*. (24)	Korea	1	2	Not reported	1	1	8 months	1 year	Large radiolucent area, no response to pulp sensibility testing	
McCabe *et al*. (26)	Ireland	1	2	1.3–1.2 × 8	1	1	10 days	5 years	Sinus tract, discomfort, slight tenderness to percussion, periapical radiolucency, positive response to pulp sensibility testing	
Ahmed *et al*. (27)	India	1	1 (case from Ahmed et al[24])	1.5 × 8.0	1†	0	4 weeks	4 weeks	No symptoms or abnormality	Pulp reparative changes can occur following obvious root penetration
Clinical/intentional injury studies										
Maino *et al*. (20)	Italy	2	4	1.5 × 8.0	4†	0	1 week	30 days	No discomfort	Drill and/or TADs contact causes resorptive root damage. Repair follows discontinuation of the contact
Kadioglu *et al*. (21)	Turkey	10	20	1.5 × 8.0	20†	0	0, 4, 8 weeks	4, 8 weeks	Not reported	Root repair occurs almost completely after cause removal
Ahmed *et al*. (25)	India	17	96	1.5 × 8.0	48†	0	0	4, 8, 12 weeks	No undue pain	Reparative cementum is formed leading to good repair after 12 weeks

(continued)

Table 1 (continued)

Author	Country	Participants	Number TAD used	Diameter × length of TAD (mm)	Number roots contacted	Teeth with pulp contact	TAD contact/use	Follow-up period	Clinical findings	Overall conclusions
Hourfar *et al.* (28)	Germany	284	568	1.7 × 8.0	0	0	15 months	2 years	Late occurrence of symptoms (pain) for the involved teeth	Loss of response to pulp sensibility testing is associated with TAD placement in proximity to teeth, in the absence of contact
Yerawedakar *et al.* (29)	India	10	40	1.6 × 8.0	40†	0	0	1 day, 3, 6,12 weeks	No undue complaints, inflammation or pain	A minimum of 12 weeks is required for root healing

†Intentional injury.

Characteristics of exposure

The diameter and length of the TADs ranged from 1.8 × 7 mm to 1.5 × 10 mm. The incidence of root contact varied from nil to 48, with two pulpal exposures occurring. TADs contact duration ranged from zero days (i.e. resulting in immediate removal of the TAD) to 2.5 years. Follow-up times were also variable, ranging between nil (i.e. immediate tooth extraction) through to 5 years.

The mechanisms of injury included contact between TADs and teeth following orthodontic movement of the latter, root damage from a pilot drill and/or TAD placement, and placement and subsequent removal of TAD following contact. A fractured TAD following attempted retrieval was also described (27). One study assessed different insertion positions in the absence of evident contact (28).

Endodontic complications associated with TADs

The complications comprised loss of pulp vitality (due to placement of TADs in proximity to the tooth), PDL contact, root contact or pulpal exposure with the subsequent development of pulpal necrosis and chronic apical periodontitis. Six studies utilised pulp sensibility testing (22–24,26–,28). Amongst these, five case reports assessed pulp sensibility following injury (22–24,26,27), with four studies reporting the development of pulpal necrosis, with subsequent chronic apical periodontitis that was confirmed radiographically (22–24,26). Hourfar and colleagues reported loss of pulp sensibility in patients in the second half of a two-year retention phase following removal of fixed appliances. The TAD had been in close proximity to the root, without directly contacting the teeth (28).

The severity of injury caused by TADs is normally reflected in the complexity of subsequent treatment. In four studies, areas of chronic apical periodontitis healed following root canal treatment (22–24,26); however, in the presence of extensive iatrogenic damage, more complex surgical procedures were additionally required (22,24,26).

When TAD injury to the root was limited to the PDL, cementum or dentine, causing minimal inflammation, a normal repair process occurred in a time-dependent fashion, with 12 weeks suggested as the required time for healing (20,21,25,27,29). Healing involved regeneration of the PDL and cementum; removal of TADs favoured healing (20). Furthermore, the presence of a mature biofilm associated with the injured area was demonstrated (22).

Discussion

This review aimed to assess the effect of TAD placement on endodontic complications and shows that the degree of injury following TAD placement was associated with the occurrence and severity of pulpal and periapical pathoses, though loss of pulpal sensibility may occur even if TADs do not contact roots (28). Clinically evident loss of hard dental tissue with pulp exposure commonly leads to necrosis and apical periodontitis (22,24,26), whereas damage limited to the PDL, cementum and dentine will often result in repair in a time-dependent fashion (20,21,25,27,29).

A strength of this review is the inclusion of studies with low possibility of bias. An *a priori* cut-off for methodological quality, that also assesses bias, is part of the systematic review methodology of the JBI (16,30–32). Studies with low methodological quality, or a moderate to high possibility of bias, or both, were excluded. This approach helps give confidence in the strength and validity of the review's results. Variable study designs were considered for inclusion, aiming to integrate the richness of the available qualitative research 'to capture the whole phenomenon of interest' (33). The results of this systematic review are in agreement with the main findings of a previously published review that focused mostly on animal studies (15), although the outcomes from animal studies may not be always extrapolated to humans (25).

Several limitations should be taken into account when considering the conclusion of this review: (i) the paucity and study design of studies in this topic, despite using high sensitivity search terms across four electronic databases, including DOSS (that covers grey literature). An explanation is publication bias. Over time, fewer journals are accepting case reports for publication. Also, clinical cases with negative outcomes are unlikely to be prepared for publication (34). Thus, other potentially negative consequences such as endodontic treatment failure and/or tooth loss are not included in this review as these are yet to be reported in the literature. Furthermore, systematic reviews of aetiology have a limitation regarding the study design of component studies, considering that it would be unethical to carry out longitudinal experimental studies (i.e. causing an intentional injury), for example (35). (ii) Studies with intentional injury may not represent clinical reality and are only followed up for a relatively short duration. Nonetheless, studies adopting this methodology add to our histological understanding of healing response following injury *in vivo*. (iii) Most of the cases (86%) originated from a single retrospective clinical study (28). Therefore, even if biological plausibility of endodontic complications related to injury with TADs is confirmed, the findings of the present systematic review should be considered with caution.

It is essential to be aware of the position of roots during pilot drill usage and placement of TADs. Similarly, teeth should not be moved without first considering whether their roots might approach existing TADs. Although there is a possibility of tooth surface repair following TAD-related injury, this should be avoided owing to the potentially important endodontic complications that can ensue. The occurrence of tooth injury and/or loss, related to TAD injury, consequently requires revision of the originally agreed treatment plan (36). Iatrogenic errors may have a negative impact on the patient's quality of life and the patient–clinician relationship, possibly leading to litigation (37). Complications can be minimised by detailed planning of TAD insertion and appropriate patient follow-up after active orthodontic treatment is completed, in order to monitor the endodontic status of teeth that were in close proximity to the area where TADs were previously placed. Finally, root contact may damage the TAD and compromise its retention.

The need for long-term monitoring for endodontic complications following the use of TADs cannot be overemphasised as the subsequent sequelae could take several years to become clinically evident. Apart from pulpal demise, orthodontic treatment has been suggested to be a predisposing factor for the development of invasive cervical resorption (ICR) (38,39), a type of resorption distinct from orthodontically induced external root resorption (OIERR). Considering that ICR is associated with a defect in the cementum/cementoid layer, the accumulative root damage related to the use of TADs and orthodontic treatment *per se*, may lead to an increase in the incidence of this insidious clinical form of external root resorption. Cementum defects due to TAD-related injury may also be associated with OIERR.

Given that TADs are becoming an increasingly popular anchorage choice in orthodontics, future studies should use a prospective longitudinal approach, adopting a combination of diagnostic procedures to more accurately evaluate pulp responses immediately before as well as following TAD placement. These outcomes should also be followed up at regular intervals, through to the retention phase of orthodontic treatment. Furthermore, in the presence of damage greater than superficial root contact, this review demonstrates that signs, symptoms or radiographic evidence of endodontic complications may subsequently occur.

TADs that are in close proximity to, or contact roots, can result in endodontic complications such as pulpal necrosis or chronic apical periodontitis. If the injury is limited to the PDL, cementum or dentine, repair is possible following removal of the TAD. Considering that, in

general, case reports and series are associated with increased possibility of bias, further clinical studies with sufficient follow-up are required to better understand potential associations between orthodontic treatment, TAD-related injuries and endodontic complications.

Conflicts of interest

All authors of the present study declare no conflict of interest.

References

1. Deguchi T, Nasu M, Murakami K, Yabuuchi T, Kamioka H, Takano-Yamamoto T. Quantitative evaluation of cortical bone thickness with computed tomographic scanning for orthodontic implants. Am J Orthod Dentofacial Orthop 2006; 129(721): e7–12.
2. Schätzle M, Männchen R, Zwahlen M, Lang NP. Survival and failure rates of orthodontic temporary anchorage devices: a systematic review. Clin Oral Implants Res 2009; 20: 1351–9.
3. Rossouw PE, Buschang PH. Temporary orthodontic anchorage devices for improving occlusion. Orthod Craniofac Res 2009; 12: 195–205.
4. Southard TE, Buckley MJ, Spivey JD, Krizan KE, Casko JS. Intrusion anchorage potential of teeth versus rigid endosseous implants: a clinical and radiographic evaluation. Am J Orthod Dentofacial Orthop 1995; 107: 115–20.
5. Aly SA, Alyan D, Fayed MS, Alhammadi MS, Mostafa YA. Success rates and factors associated with failure of temporary anchorage devices: a prospective clinical trial. J Investig Clin Dent 2018; 9: e12331.
6. Sandler J, Murray A, Thiruvenkatachari B, Gutierrez R, Speight P, O'Brien K. Effectiveness of 3 methods of anchorage reinforcement for maximum anchorage in adolescents: a 3-arm multicenter randomized clinical trial. Am J Orthod Dentofacial Orthop 2014;146:10–20.
7. Koyama I, Iino S, Abe Y, Takano-Yamamoto T, Miyawaki S. Differences between sliding mechanics with implant anchorage and straight-pull headgear and intermaxillary elastics in adults with bimaxillary protrusion. Eur J Orthod 2011; 33: 126–31.
8. Hu K-S, Kang M-K, Kim T-W, Kim K-H, Kim H-J. Relationships between dental roots and surrounding tissues for orthodontic miniscrew installation. Angle Orthod 2009; 79: 37–45.
9. Costa A, Raffainl M, Melsen B. Miniscrews as orthodontic anchorage: a preliminary report. Int J Adult Orthodon Orthognath Surg 1998; 13: 201–9.
10. Huang CT, Hsiang-Hua Lai E, Chang HH *et al*. Damage to the root after tooth movement towards a temporary anchorage device: an animal pilot study. J Dent Sci 2012; 7: 171–8.
11. Jung Y-R, Kim S-C, Kang K-H *et al*. Placement angle effects on the success rate of orthodontic microimplants and other factors with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2013; 143: 173–81.
12. Doğramacı EJ, Rossi-Fedele G. The quality of information on the Internet on orthodontic retainer wear: a cross-sectional study. J Orthod 2016; 43: 47–58.
13. Rossi-Fedele G, Musu D, Cotti E, Doğramacı EJ. Root canal treatment versus single-tooth implant: a systematic review of internet content. J Endod 2016; 42: 846–53.
14. Alves M Jr, Baratieri C, Mattos CT, De Souza Araújo MT, Maia LC. Root repair after contact with mini-implants: systematic review of the literature. Eur J Orthod 2013; 35: 491–9.
15. Gintautaitė G, Kenstavičius G, Gaidytė A. Dental roots' and surrounding structures after contact with orthodontic mini-implants: a systematic literature review. Stomatologija 2018; 20: 73–81.
16. Moola S, Munn Z, Sears K *et al*. Conducting systematic reviews of association (etiology): the Joanna Briggs Institute's approach. Int J Evid Based Healthc 2015; 13: 163–9.
17. Moher D, Liberati A, Tezlaff J *et al*. Preferred reporting statement for reporting systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med 2009; 151: 264–9.
18. The University of Adelaide, The Joanna Briggs Institute. Checklist for Quasi-Experimental Studies (non-randomized experimental studies). Available from: https://wiki.joannabriggs.org/pages/viewpage.action?pageId=9273720 Accessed 21 May 2019. Archived at WebCite® at: http://www.webcitation.org/78WwRcyTu
19. The University of Adelaide, The Joanna Briggs Institute. Checklist for Case Reports. Available from: https://wiki.joannabriggs.org/display/MANUAL/Appendix+7.4+Critical+appraisal+checklist+for+case+reports Accessed 21 May 2019. Archived at WebCite® at: http://www.webcitation.org/78Wwe4BXj
20. Maino BG, Weiland F, Attanasi A, Zachrisson BU, Buyukyilmaz T. Root damage and repair after contact with miniscrews. J Clin Orthod 2007; 41: 750–62.
21. Kadioglu O, Buyukyilmaz T, Zachrisson BU, Maino BG. Contact damage to root surfaces of premolars touching miniscrews during orthodontic treatment. Am J Orthod Dentofacial Orthop 2008; 134: 353–60.
22. Lim G, Kim K-D, Park W, Jung B-Y, Pang N-S. Endodontic and surgical treatment of root damage caused by orthodontic miniscrew placement. J Endod 2013; 39: 1073–7.
23. Er K, Bayram M, Tasdemir T. Root canal treatment of a periradicular lesion caused by unintentional root damage after orthodontic miniscrew placement: a case report. Int Endod J 2011; 44: 1170–5.

24. Hwang Y-C, Hwang H-S. Surgical repair of root perforation caused by an orthodontic miniscrew implant. Am J Orthod Dentofacial Orthop 2011; 139: 407–11.
25. Ahmed VKS, Rooban T, Krishnaswamy NR, Mani K, Kalladka G. Root damage and repair in patients with temporary skeletal anchorage devices. Am J Orthod Dentofacial Orthop 2012; 141: 547–55.
26. McCabe P, Kavanagh C. Root perforation associated with the use of a miniscrew implant used for orthodontic anchorage: a case report. Int Endod J 2012; 45: 678–88.
27. Ahmed VKS, Krishnaswamy NR, Thavarajah R. Miniscrew implant fracture and effects of such retained tip on dentin-pulp complex: a histological report. Dent Traumatol 2016; 32: 161–5.
28. Hourfar J, Bister D, Lisson JA, Ludwig B. Incidence of pulp sensibility loss of anterior teeth after paramedian insertion of orthodontic mini-implants in the anterior maxilla. Head Face Med 2017; 13: 1.
29. Yerawadekar SA, Rahalkar JS, Darda M, Sarode SC. Sarode GS. Histological evaluation of root repair after damage due to intentional contact with orthodontic micro-screw implants: an *in vivo* study. J Clin Diagnostic Res 2018; 12: ZC01-4.
30. Doğramacı EJ, Rossi-Fedele G. Establishing the association between nonnutritive sucking behavior and malocclusions: a systematic review and meta-analysis. J Am Dent Assoc 2016; 147: 926–34.
31. Doğramacı EJ, Rossi-Fedele G, Dreyer CW. Malocclusions in young children: does breastfeeding really reduce the risk? A systematic review and meta-analysis. J Am Dent Assoc 2017; 148: 566–74.
32. Arraj GP, Rossi-Fedele G, Doğramacı EJ. The association of overjet size and traumatic dental injuries – a systematic review and meta-analysis. Dent Traumatol 2019; 35: 217–232.
33. Joanna Briggs Institute. Reviewers' Manual. Adelaide: The University of Adelaide; 2014. p. 14.
34. Musu D, Rossi-Fedele G, Campisi G, Cotti E. Ultrasonography in the diagnosis of bone lesions of the jaws: a systematic review. Oral Surg Oral Med Oral Pathol Oral Radiol 2016; 122: e19–29.
35. Marshall G, Canullo G, Logan RM, Rossi-Fedele G. Histopathological and microbiological findings associated with retrograde peri-implantitis of endodontic origin: a systematic and critical review. Int J Oral Maxillofac Surg 2019; 48: 1475–84.
36. Doğramacı EJ, Sherriff M, Rossi-Fedele G, McDonald F. Location and severity of root resorption related to impacted maxillary canines: a cone beam computed tomography (CBCT) evaluation. Aust Orthod J 2015; 31: 49–58.
37. Barnes PL, Rossi-Fedele G. Excessive heat-associated gingival necrosis: a case report. Aust Dent J 2017; 62: 382–5.
38. Heithersay GS. Invasive cervical resorption: an analysis of potential predisposing factors. Quintessence Int 1999; 30: 83–95.
39. Heithersay GS. Invasive cervical resorption. Endod Top 2004; 7: 73–92.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Electronic database search strategies.

Table S2. Characteristics of excluded studies at eligibility phase.

Table S3. Possibility of bias. Possibility of bias summary: Reviewers' judgment about each risk of bias for each included study.