



Review article

Effectiveness of surgical procedures in the acceleration of orthodontic tooth movement: Findings from systematic reviews and meta-analyses

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ABSTRACT

The current overview aimed to summarise the findings provided by systematic reviews (SRs) on the effect of surgical procedures in the acceleration of tooth movement and to assess the methodological quality of the included SRs. Three electronic databases have been explored. SRs addressing the effects of surgical procedures on the acceleration of tooth movement were included. The methodological quality of the included SRs was assessed using the updated version of "A Measurement Tool to Assess Systematic Review" (AMSTAR-2). Twenty-eight (28) SRs were included. The methodological quality of the included reviews ranged between critically low (6 studies) and high (12 studies). The most common critical weakness in the included reviews was the absence of clearly a-prior established review methods and any significant deviations from the protocol. The most studied surgical procedure was corticotomy, followed by micro-osteoperforation, piezocision and periodontally accelerated osteogenic orthodontics. The majority of the included SRs supported short-term favourable effects of corticotomy on treatment time and tooth movement rate, in the short-term. However, the authors of the included SRs reported that results were based on weak quality evidence. Conflicting results arise from the existent SRs with regards to the effectiveness of piezocision and micro-osteoperforation. Few SRs summarised complications and side effects of surgical techniques, supporting absence of loss of tooth vitality, periodontal problems, or severe root resorption. The current overview of SRs highlighted the need of high quality SRs comparing different surgical approaches for tooth movement acceleration through network meta-analysis, in order to determine the most efficient instrument for orthodontic movement acceleration.

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1. Introduction

One of the major concerns of orthodontic patients before starting an orthodontic treatment, apart from treatment results, is the duration of the treatment. In the literature, average orthodontic treatment time (OTT) has been estimated of approximately 2 years [1]. Several factors have been investigated as variables contributing to orthodontic treatment length, such as clinicians' expertise, extraction treatment plan, severity of the initial malocclusion, inter-individual differences in biological responses and patient's compliance and appointments adherence [2,3]. Furthermore, recent findings pointed out that also bone anatomy and cortical bone thickness are negatively correlated to overall orthodontic treatment duration [4]. Increased orthodontic treatment duration can have adverse effects on teeth and surrounding tissue, such as spot lesion and dental caries, external apical root resorption, gingivitis and periodontitis [5,6]. Moreover, nowadays an increasing number of adult patients demand orthodontic treatment for aesthetic purposes, and short treatment time is a primary request for aesthetic and social concerns [7]. In fact, recent findings from an interview study is showed that patients are willing to undergo additional procedures to reduce the treatment duration and to bear additional costs [8].

In this regard, various surgical and non-surgical approaches (i.e. photobiomodulation [9], corticotomy [10], low-level laser therapy [11], micro-osteoperforation [12], and piezocision [13]) have been proposed to accelerate the orthodontic tooth movement (OTM), in order to reduce the overall duration of orthodontic treatment. Systematic Reviews (SRs) are the preferred publication type to collect existing evidences, and to offer the clinicians a summary of the most updated findings, in order to answer to a clinical question from the scientific literature [14]. In particular, numerous SRs have been conducted to assess the effects of surgical procedures in the acceleration of tooth movement, presenting different inclusion/exclusion criteria and conflicting results. Moreover, the variation in the quality of primary studies, methodology and publication time produces difficulties in the evaluation of the evidence and decision making.

With the increasing number of SRs available in the same topic area, the logical next step to provide decision makers in healthcare with the evidence they need is to perform overviews of these SRs. Overviews of SRs are similar to reviews of interventions, but the unit of searching, inclusion and data analysis is the SR rather than the primary study. Overviews of SRs are often broad in their scope, and aim to provide an "user-friendly" summary of the results from the multiple SRs and meta-analyses. Finally, overviews of SRs provide quality assessment on the existing SRs on a given topic, describing the current body of SRs evidence on a topic of interest, and highlighting the evidence gap in the existent literature. Therefore, overview of SRs are important tool for clinicians to guide their treatment planning based upon the highest level of evidence, and for researcher to recognize topic to be prioritised in future researches.

One previous overview of SRs summarised the findings regarding surgical and non-surgical interventions on the acceleration of orthodontic tooth movement [15]. The authors conducted their

literature search up to August 2016, and identified 11 SRs concluding that low-level laser therapy and corticotomy were effective to promote orthodontic tooth movement in the short term, although these findings were supported by low quality evidence. Due to the increasing amount of primary studies published on the topic of orthodontic tooth movement acceleration, numerous additional SRs have been published following the last Overview of SRs, pointing out the need to perform a new summary of findings. Therefore, this overview aimed to summarise the findings provided by SRs on the effects of surgical procedures in the acceleration of orthodontic tooth movement and to assess the methodological quality of the published SRs.

2. Materials and methods

According to the PICO (*P: population, I: intervention, C: comparison, O: outcome*) statement, this overview aimed to answer to the question "Do surgical procedures (Intervention) modify the overall orthodontic treatment time and the tooth movement rate (Outcome) in orthodontic patients wearing fixed orthodontic appliances (Population)?" All surgical techniques described in the current scientific literature for tooth movement acceleration purpose were included as "Interventions". Untreated controls, conventional orthodontics, and acceleration procedures other than surgical were considered as "Comparisons". Secondary outcomes were side effects and complications (i.e. periodontal outcomes, root resorption, pain, discomfort, swelling, hypersensitivity, etc.).

The protocol was registered on the PROSPERO National Institute of Health Research Database (CRD42021258587).

2.1. Literature search and review selection

Three electronic databases (PubMed, Scopus, The Cochrane Library) have been explored up to December 2020 using combinations of keywords and MeSH terms according to the database rules (Table 1). A manual search on orthodontic journals (European Journal of Orthodontics, American Journal of Orthodontics and Dentofacial Orthopedics and The Angle Orthodontist) and a further search among the references of the included papers were performed. An effort of exploration of the grey literature was done by searching among the conference abstracts published on Web of Science and Scopus and on the databases of scientific dental congresses (European Orthodontic Society and International Association of Dental Research). Two authors (RG, FDR) separately carried out the electronic literature search. SRs and meta-analyses addressing the effects of surgical procedures in the acceleration of tooth movement were included. After title and abstract screening, the articles were selected for full-text reading. Whenever differences in the judgement of the eligibility of title and abstract occurred, full texts were included for final assessment. Dual publications, narrative reviews, animal or laboratory study, updated publications, data from ongoing studies, acceleration techniques other than surgery (vibration, low

Table 1
Search strategy for each database and relative results.

Database	Search strategy
Pubmed	("orthodontics"[MeSH Terms] OR "orthodontic"[All Fields] OR "malocclusion"[MeSH Terms] OR "Tooth Movement Techniques"[MeSH Major Topic]) AND ("accelerated tooth movement"[All Fields] OR "corticotomy"[Title/Abstract] OR "bone grafting"[Title/Abstract] OR "piezocision"[Title/Abstract] OR "osteotomy"[Title/Abstract] OR "osteoperforation"[Title/Abstract] OR "corticision"[Title/Abstract] OR "piezotomy"[Title/Abstract]) AND ("review"[Publication Type] OR "meta-analysis"[Publication Type])
Scopus	(TITLE-ABS-KEY (orthodontic*) OR TITLE-ABS-KEY (malocclusion*)) AND (TITLE-ABS-KEY ("accelerated tooth movement") OR TITLE-ABS-KEY (corticotomy) OR TITLE-ABS-KEY ("bone grafting") OR TITLE-ABS (piezocision) OR TITLE-ABS-KEY (osteotomy) OR TITLE-ABS-KEY (osteoperforation) OR TITLE-ABS-KEY (corticision) OR TITLE-ABS-KEY (piezotomy)) AND (LIMIT-TO (DOCTYPE, "re"))
Cochrane	(accelerated orthodontic tooth movement):ti,ab,kw

lever laser therapy, etc.) were excluded. Articles written in any language other than English were excluded.

Disagreements between the two investigators were solved through discussion; if needed, a third operator (RB) was contacted for final decision.

2.2. Data extraction

Data were independently extracted by two authors (RG, FDR) using a pre-determined extraction form. Whenever the information provided in the SR were not clear, the individual studies have been consulted. The authors were not contacted for further details. The following data were extracted: author, publication year, study design (SR with or without meta-analysis), total number of subjects included, search period, databases, intervention and control groups, outcome measures, methods of measurement, quality tool and quality of the individual studies, results, author's conclusion.

2.3. Methodological quality of included reviews

The methodological quality of the included SRs was independently assessed by two reviewers (RG and RB) using the revised and updated version of A Measurement Tool to Assess Systematic Review (AMSTAR-2) [16]. AMSTAR-2 is a valid and reliable instrument composed by 16 items, each categorised into a standardised set of three or two possible responses: "yes," "partial yes" or "no." After interpreting weaknesses detected in critical and non-critical items, the overall rating of the quality of the SR was reported as "high," "moderate," "low" or "critically low".

3. Results

3.1. Search results

A total of 524 records were identified through electronic and manual search. After duplicates removal, title and abstracts of 425 records were screened. Afterwards, 38 manuscripts were included for full text reading, of which 10 were excluded according to the pre-determined exclusion criteria and the most common exclusion criterion was the absence of a systematic search strategy (see Table S1 for the references of the excluded full-text and reasons). Finally, 28 SRs were included in the current overview [17–44]. The selection process is given in Fig. 1.

3.2. Characteristics of included reviews

Summarised data extracted from the 28 SRs are presented in Table 2. The number of primary studies included in each SR ranged between 2 and 29. Twelve (12) SRs were integrated with a meta-analysis.

Most of the SRs included as primary study clinical controlled studies and randomised clinical trials, but 4 SRs included also non-controlled studies and case series. None of the included reviews was based on non-controlled studies only. The number of total

subjects included in each review ranged between 31 and 618. The initial orthodontic diagnosis was not clearly specified in any of the included reviews. The most studied surgical procedures studied were corticotomy, followed by micro-osteoperforation and piezocision. Surgical acceleration of the tooth movement was compared to conservative orthodontic treatment and/or untreated control group. The primary outcomes in most of the studies were rate of tooth movement (RTM- 17 studies) and OTT or OTM. Other reported outcomes were periodontal parameters, root resorption, pain and discomfort.

3.3. Methodological quality of included reviews

The methodological quality of the included reviews as measured with the AMSTAR-2 ranged from critically low (6 studies) to high (12 studies). The most common critical weakness in the included reviews was the absence of clearly a-prior established review methods and any significant deviations from the protocol (Table 3).

3.4. Clinical findings

3.4.1. Corticotomy

Corticotomy was the most frequently reported surgical procedure associated to orthodontic treatment, addressed in 17 out of the 28 included SRs [19,21,23,24,26–30,32,33,35–37,39,40,43]. Corticotomy was generally defined as a surgical procedure in which the cortical bone was cut, perforated or mechanically altered, without affecting the medullary bone.

Most of the included SRs addressing this topic agreed that corticotomy prior to the commencement of an orthodontic tooth movement was a safe and effective treatment to accelerate the rate of dental movement, reducing the overall treatment time. [19,24,36,39].

Gil and co-workers [28] reported a mean total treatment time of 8.85 months following corticotomy, whereas in the control group (conventional treatment) the duration was 16.4 months on average, supporting a decreased treatment time after surgical intervention. Similarly, Hassan and co-workers pointed out that corticotomy accelerated the OTM by 2–2.5 folds when compared to conventional treatment [30], and Darwike and colleagues showed that corticotomy accelerated the OTM by 2–2.3 folds, but the authors underlined that level of evidence supporting these findings was too low to draw valid conclusions [21]. With similar results, Viwattanatipa showed that corticotomy induced a more significant (i.e., 2–4 times faster) increase in the rate of tooth movement than did the conventional method [43]. Fleming and collaborators reported that tooth movement was slightly quicker with corticotomy in comparison with conventional treatment over periods of one month (MD 0.61 mm; 95% CI 0.49–0.72; P value < 0.001) and three months (MD 2.03 mm, 95% CI 1.52–2.54; P value < 0.001) [26]. Kalemaj and colleagues found that, in the short-term, corticotomy can accelerate RTM up to 2.3 times whereas long-term effects are questionable, thus no firm conclusions can be made on its efficacy and benefit of clinical use [33].

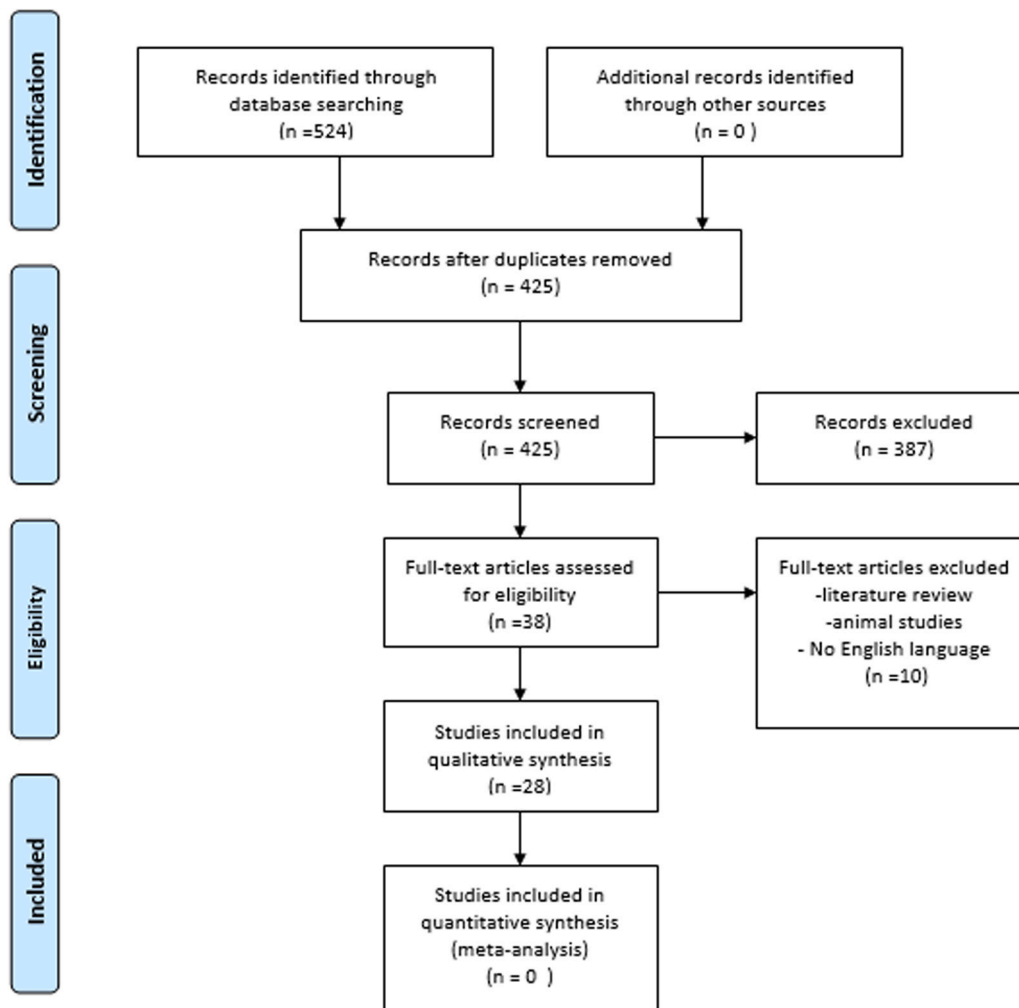


Fig. 1. PRISMA Flow Diagram of the included and excluded records.

Fu and co-workers pointed out after flapless corticotomy procedures, increased canine retraction movement rates by weighted mean differences of 0.63 mm ($P = 0.003$) and 0.64 mm ($P = 0.16$) at 1 and 2 months follow-up, respectively. The mean treatment time was 68.42 days ($P = 0.003$) less than that for minimally invasive surgery, with only low-quality evidence to prove it [27]. Similar findings were observed by Gkantidis and colleagues, observing higher canine retraction rate following corticotomy during the first month of therapy ($P < 0.01$) in a period longer than 3 months, but the level of evidence observed by the authors supporting this intervention was low [29]. MacDonald et al. [37] showed that the best adjunctive therapy to accelerate the canine retraction for the first 2 months of treatment was corticotomy, followed by piezocision, in comparison with conventional orthodontic treatment. In addition, Khlef and colleagues found no significant difference was found between en-masse/flapless corticotomy and en-masse/control groups in terms of anterior teeth retraction ($p = 0.661$); while there was a significantly greater anterior teeth retraction in corticotomy with flap elevation group compared to control group ($p < 0.001$). [35].

With regards to side effects, no periodontal damage was found [23,24,29,40], although this was only studied in the short term. Moreover, no or little risk of root resorption [30] or vitality loss [32] were observed while minor complications, such as pain, swelling and dentine hypersensitivity, seemed to be more frequent [28].

3.4.2. Periodontally accelerated osteogenic orthodontics (PAOO) and corticotomy-accelerated osteogenic orthodontic treatment (CAOOT)

Two SRs [34,42] reported results from PAOO technique and one SR [20] reported results from CAOOT technique. Differently from conventional corticotomy, PAOO and CAOOT included concomitant bone grafting and augmentation.

Vannala et al. reported contradictory results of PAOO effect on treatment duration [42], whereas Kamal and co-workers [34] showed reduced treatment duration and significant improvement in overall periodontal health through evaluation of probing depth following PAOO.

According to Dab and colleagues, CAOOT appeared to accelerate the tooth movement during the first few months and to increase the bone thickness and bone density, but the clinical significance of these changes was considered questionable. Moreover, CAOOT seemed to reduce en-masse retraction time of the upper anterior teeth compared to conventional treatment by 2.80 months. However, the authors reported that level of the body of evidence ranged from very low to low [20].

3.4.3. Piezocision

Piezocision was assessed in 9 SRs [17,19,25,27,31,37,38,43,44]. In general, with the term “piezocision” the authors referred to a technique including cutting tip used under copious irrigation, to make the cortical incisions through the soft tissue.

Table 2
Characteristics of included reviews.

Author, Year of publication	Search period	Databases	Study design: total n. of subjects	Diagnosis	Intervention	Control	Quality of the primary studies	Outcomes	Conclusions
Alfawal et al., 2016 [17]	up to January 2016	Cochrane Central Register of Controlled Trials (CENTRAL), EMBASE, Scopus, PubMed, Web of Science, Google Scholar Beta, Trip, OpenGrey and PQDT OPEN from proQuest	SR of 4 RCT; 61 subjects	Class II div I; mandibular anterior crowding: patients who need to extract 1st premolars and maxillary canine retraction	MOP, piezocision, interseptal bone reduction	conventional orthodontic treatment	Unclear risk of bias for all studies	primary outcomes: RTM, time of tooth movement, cumulative tooth movement; secondary outcomes: Pain and discomfort; Inflammatory, Canine tipping, Canine rotation, Molar anchorage loss, Transversal changes, Mobility scores, Gingival indices, RTM	There is limited and low-quality evidence concerning the efficacy of Minimally invasive surgically accelerated orthodontics (MISAO) in acceleration orthodontic tooth movement. Therefore, MISAO cannot currently be recommended in everyday clinical practice, although the acceleration of canine retraction appeared to be significant at least in the first 2 months
Al-Khalifa et al., 2020 [18]	NR	MedLine via PubMed, Google Scholar, Scopus, and Web of Science	SR of 11 RCTs; 302 subjects	NR	MOP	NR	NR	RTM	MOPs are proving to be a minimally invasive, repeatable, relatively easily surgical procedure. Patients have reported very mild and insignificant discomfort and pain after receiving MOPs as compared with those who undergo conventional orthodontic treatment procedures. Insignificant external root resorption is reported with this procedure in comparison to corticotomies and osteotomies. Patient compliance is high.
Apalimova et al., 2020 [19]	up to December 2018	PubMed, Web of Science, Scopus and ScIELO databases	SR of 9 studies; 210 subjects	Class II div I, Class II div II, Class I skeletal with light or moderate crowding	Corticotomy, piezocision	conventional orthodontic treatment	6 high risk of bias; 3 low risk of bias.	RTM, Periodontal parameters, Bone density, Root resorption	Corticotomy procedures involve a rate increase in dental movement and acceleration during the first months. It does not seem to involve major complications, such as root resorption, affection at periodontal level or pulpal vitality, in comparison to conventional treatments. However, low quality and high heterogeneity among studies makes it difficult to draw clear conclusions
Dab et al., 2018 [20]	up to August 2018	MEDLINE via OvidSP, Scopus, EMBASE via OvidSP and Web of Science	SR of 12 studies: 5 RCTs split-mouth, 4 RCTs parallel arms, 1 RCT and 2 prospective CCTs; 206 subjects	Adults with Class I malocclusion with anterior crowding and Class II div 1 malocclusion with mild to moderate crowding	CAAO	conventional orthodontic treatment	3 unclear risk of bias, 2 high risk of bias and 8 low risk of bias.	Periodontal parameters (periodontal probing depth, gingival index, plaque index, recession); Bone density; Buccal bone thickness (crestal level, midroot level, apical level);	Current evidence suggests a very low to low level of certainty in regard to quantified effects after corticotomy. Although corticotomy procedures show an insignificant increase in the density following the use of bone graft and anchorage loss, they appear to accelerate the tooth movement during the first few months, to increase the buccal bone thickness and to show good tolerance by the patients; the clinical significance of these changes may be considered questionable

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Table 2 (continued)

Author, Year of publication	Search period	Databases	Study design; total n. of subjects	Diagnosis	Intervention	Control	Quality of the primary studies	Outcomes	Conclusions
Darwiche et al., 2020 ^[21]	up to January 2018	PubMed and Google Scholar	SR of 29 studies	NR	corticotomy	conventional orthodontic treatment	NR	RTM, time of tooth movement, periodontal parameters;	Although the current review indicates that accelerated orthodontic treatment is characterized by a temporary phase of tooth movement that can fasten the treatment duration by 2.2–3 folds compared to conventional orthodontic treatment, there is limited available evidence about effectiveness of corticotomy-assisted accelerated orthodontics
Dos Santos et al., 2020 ^[22]	until May 2020.	PubMed, Cochrane, Web of Science, LILACS, Google Scholar, Scopus, and OpenGrey.	SR of 12 RCTs: 8 split-mouth and 4 parallel control group; 332 subjects	Class I; Class II/1; Class III	MOP	conventional orthodontic treatment	4 low risk of bias, 5 some concerns ad 3 high risk of bias	primary outcomes: RTM measured by the amount of canine retraction or total anterior retraction; Secondary outcomes: quality of life, impact on patient's daily routine, pain/discomfort, root resorption, periodontal health, and anchorage loss.	Current scientific evidence with low certainty points to no effect of MOPs on orthodontic movement rate when using the PROPEL system, as well as other mini-screws. The MOPs seem to have no effect on root resorption, loss of anchorage, periodontal health, and pain/discomfort. They also produced more impact on the quality of life immediately following the perforations and for 3 days after.
Ferguson et al., 2018 ^[23]	up to September 2018	Medline, PubMed Central, Scopus, Embase, and Google Scholar	SR of 2 studies	NR	Corticotomy, MOP, corticision	conventional orthodontic treatment	NR	Bone markers level: pre-osteoclast and osteoclast count, TNFa	Data from bone biomarkers clearly showed differences between accelerated orthodontic treatment and conventional treatment, but the differences were not enough to discriminate catabolic bone activity among the acceleration techniques corticotomy, micro-osteoperforation, and corticision
Fernández-Ferrer et al., 2016 ^[24]	until June 2015	Pubmed, Scopus, Cochrane Library and Embase	SR of 16 studies: 4 systematic reviews, 11 RCTs and 1 CCT	NR	corticotomy	conventional orthodontic treatment	NR	Primary outcomes: speed of tooth movement, time od tooth movement; Secondary outcomes: periodontal health, postoperative pain, loss of posterior anchorage, inflammation markers, root length and canine rotation and tipping.	Within the limitations of this review, the results of the studies included confirm that combining conventional orthodontic treatment with corticotomy reduces the duration of the treatment by accelerating tooth movement. However, few clinical trials have been conducted to date in this area, with small samples of patients and short-term follow-up, so the efficiency-safety ratio is not conclusive
Figueredo et al., 2019 ^[25]	up to March 30, 2019	Medline/PubMed (Medical Literature Analysis and Retrieve System Online), EMBASE, Cochrane Central	SR of 4 CCTs and 7 RCTs with parallel group; 240 subjects	NR	piezocision	conventional orthodontic intervention associated or not with other type of	6 RCTs presented an unclear risk of bias and 1 showed a high risk of bias; 1	RTM; accumulative movement distance; TOTI; anchorage control; periodontal parameters; root	Although the majority of the included studies reported a tendency of OTM acceleration using piezocision, the quality of evidence is low to confirm that performing piezocision

(continued on next page)

Table 2 (continued)

Author, Year of publication	Search period	Databases	Study design; total n. of subjects	Diagnosis	Intervention	Control	Quality of the primary studies	Outcomes	Conclusions
Fleming et al., 2015 [26]	up to September 2014	Register of Controlled Trials (CENTRAL) and Latin American and Caribbean Health Sciences (LILACS)	SR of 4 RCTs split-mouth; 57 subjects	NR	Distraction of the periodontal ligament; Distraction of the dento-alveolus; Alveolar decortication; Corticision; corticotomy	Conventional orthodontic treatment without surgical assistance	CCT has serious bias; the other CCTs were classified as having moderate risk of bias NR	resorption; patient satisfaction; pain	significantly accelerate orthodontic tooth movement.
Fu et al., 2019 [27]	up to February 2019	PubMed, CENTRAL (Cochrane Central Register of Controlled Trials), Embase, Scopus, Web of science, Science Direct, and Medline	SR of 14 RCTs 2 split-mouth, 2CCT; 1 CCT multiarm; 538 subjects	NR	Piezocision; MOP; laser-assisted flapless corticotomy; interseptal bone reduction.	conventional orthodontic treatment or another type of acceleration in combination with orthodontic treatment.	2 trials low risk of bias; 5 high risk of bias; and 12 unclear risks of bias.	RTM; OTT; pain and discomfort; gingival and periodontal complications, the loss of anchorage and unwanted tooth movement, iatrogenic harm, stability of treatment in the long term	There is not sufficient evidence to determine whether a single use of micro-osteoperforation can accelerate tooth movement. There is only low-quality evidence that flapless corticotomy procedures could accelerate tooth movement. Minimally invasive surgery has some effect on accelerating tooth movement; however, the high heterogeneity affects the reliability of the meta-analysis Corticotomies can be a powerful and safe tool to improve the quality and duration of orthodontic treatments.
Gil et al., 2018 [28]	December, 2016	MEDLINE (via PubMed), Cochrane, and EMBASE	SR of 6 case series, 6 RCTs, 1 controlled trial; 282 subjects	Class I, Class II/1 Class II/2, Class III, maxillary and mandibular protrusion and open bite.	corticotomy	conventional orthodontic treatment	7 studies high risks of bias and 6 studies medium risks of bias	OTT; periodontal parameters; loss of tooth vitality; density hypersensitivity; Pain; Swelling; Hematomas.	Corticotomies can be a powerful and safe tool to improve the quality and duration of orthodontic treatments.
Gkantidis et al., 2014 [29]	up to March 2014	Pubmed, EMBASE, Google scholar beta, and all Cochrane Databases	SR of 7 RCTs and 1 CCT split mouth; 121 subjects	lower anterior crowding; Class II/1; Bilateral palatal impacted canines; Class I with crowding or/and unilateral crossbite	corticotomy and interseptal bone reduction	alternative accelerating intervention or orthodontic treatment.	unclear risk in 4 studies and high in 4 studies.	RTM; OTT; PP (probing depth, level of effects.	There is low evidence on corticotomy regarding their effectiveness in acceleration of OTT. The evidence on interseptal bone reduction is limited. Overall, the results should be interpreted with caution given the small number, quality, and heterogeneity of the included studies.
Hassan et al., 2015 [30]		MEDLINE, PubMed, Evidence Based	SR of 5 studies; 4 RCTs and 1	NR	corticotomy	NR	NR	RTM; OTT; PP (probing depth, level of effects.	Corticotomy-assisted orthodontic treatment (CAOT) was found an

(continued on next page)

Table 2 (continued)

Author, Year of publication	Search period	Databases	Study design: total n. of subjects	Diagnosis	Intervention	Control	Quality of the primary studies	Outcomes	Conclusions
	up to July 2013	Medicine, Evidence Based Medicine (EBM) reviews American College of Physicians journal club, and allEBM Cochrane Research Systems databases	retrospective controlled trial: 61 subjects					attachment, gingival recession, and bone density)	effective method in accelerating tooth movement. The conclusions taken from these studies should be considered with caution. CAOT is a safe procedure with similar periodontal health to conventional orthodontic treatment. The CAOT exhibit no or fewer risk on root resorption.
Hoffmann et al., 2017 ^[31]	up to May 2016	PubMed and GoogleScholar	SR of 13 articles: 9 case series and 4 clinical trials; 93 subjects	Class II/1 and ClassII/2; upper and lower crowding, Class III, cross bite, deep bite	piezocision and osteoperforation	conventional orthodontic treatment or another type of acceleration in combination with orthodontic treatment	Overall high	OTT; RTM.	There is very limited evidence that minimally invasive corticision with a piezotome or orthodontic tooth movement and in the further course reduce the time of orthodontic treatment. The existing studies must be interpreted with caution because of the small number of participants, the heterogeneity of their study design and their short observation period.
Hoogveen et al., 2014 ^[32]	until April 2013	PubMed, Embase, and Cochrane databases	SR of 18 studies: 4 RCTs (3 with a split-mouth design) and 3 CCT; 11 case series; 286 subjects	NR	corticotomy, dentoalveolar distraction	conventional orthodontic treatment	moderate or low quality.	RTM; tooth vitality loss; periodontal parameters; root resorption;	Surgically facilitated orthodontics is characterized by a temporary phase of accelerated tooth movement that is not associated with complications such as loss of tooth vitality, periodontal problems, or severe root resorption. However, the level of evidence is limited owing to shortcomings in methodologies and the small numbers of patients in the studies. Due to a lack of comparative data, it is unclear which surgical protocol is preferable regarding treatment efficiency and safety.
Kalemaj et al., 2015 ^[33]	until July 2014	PubMed, Scopus, Cochrane and Google Scholar	SR of 7 studies: 3 RCT split-mouth and 4 RCT Parallel; 28; 98 subjects	NR	corticotomy and Interseptal bone reduction	conventional orthodontic treatment	1 study of high risks of bias, 3 studies of medium risks of bias, 3 studies of low risks	CTM; RTM; OTT; periodontal parameters, root resorption	Corticotomy seems to provide benefits to OT by accelerating OTM during the first months after the intervention, whereas the long-term effects are questionable. A lack of consistency amongst different investigations prevents solid conclusions from being made about the benefits of this intervention on everyday orthodontic practice. Highly limited, research-based evidence suggests that other surgical approaches such as interseptal bone reduction, can accelerate OTM. As of yet no firm conclusions

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Table 2 (continued)

Author, Year of publication	Search period	Databases	Study design; total n. of subjects	Diagnosis	Intervention	Control	Quality of the primary studies	Outcomes	Conclusions
Kamal et al., 2019 ^[34]	up to November 2017	PubMed, Cochrane, Embase and EBSCO CINAHL complete.	SR of 5 RCTs; 101 subjects	NR	PAAOT; 3 studies corticotomy with bioactive glass graft, 1 corticotomy with bovine bone, 1 corticotomy with allograft	conventional orthodontic treatment or modified corticotomy	high risk of bias was prevalent	OTT; root resorption; periodontal parameters; bone density	can be made on their efficacy and clinical benefit. Included studies showed significant improvements in periodontal health. Treatment duration was reduced in patients who underwent periodontally accelerated osteogenic orthodontics. Root resorption was not sufficiently evaluated by current literature
Khief et al., 2019 ^[35]	up to April 2018	PubMed, Medline, OVID SP, Embase, Scopus, EBSCO, Google Scholar, the Cochrane Central Register of	SR of 8 studies; 6 RCTs and 2 CCTs; 255 subjects	Bimaxillary protrusion; Class I or II dentoalveolar protrusion; Class II Division 1; Class II or I bimaxillary protrusion	Flapless corticotomy or corticotomy with flap elevation	conventional orthodontic treatment	1 trial was of low risk of bias, 4 trials were of unclear risk of bias and 1 trial was of high risk of bias	OTT or canine retraction time	No significant difference was found between en-masse/flapless corticotomy and en-masse/control groups in terms of anterior teeth retraction while there was a significantly greater anterior teeth retraction in corticotomy with flap elevation group compared to control group. However, the strength of evidence is not strong and requires additional research work
Long et al., 2013 ^[36]	up to August 2011	PubMed, Embase, Science Citation Index, CENTRAL and SINGLE	SR of 3 studies; 2 RCTs and 1 Quasi-RCT; 31 subjects	NR	corticotomy and dentoalveolar distraction	NR	1 study high; 1 study medium; 1 study low	RTD; CTM; Periodontal Parameters; Pulp vitality; Root resorption.	Corticotomy is safe and able to accelerate orthodontic tooth movement; Dentoalveolar or periodontal distraction is promising in accelerating orthodontic tooth movement but lacks convincing evidence
MacDonald et al., 2020 ^[37]	up to April 2020	MedLINE, EMBASE, Cochrane CENTRAL, CINAHL and SCOPUS	SR of 10 RCTs	NR	corticotomy, piezocision and MOP	NR	1 study high; 5 study moderate and 4 study low	RTM	Low to very low quality of evidence from randomized control trials reported in the literature suggests that corticotomy appears to be the most efficacious adjunctive therapy for the acceleration of maxillary canine retraction for the first 2 months of treatment analysed. Low-to-moderate quality of evidence suggests that piezocision, MOP were also efficacious adjunctive treatments for accelerating OTM in the first month of treatment but not thereafter
Mheissen et al., 2019 ^[38]	up to April 2019	Cochrane database, Cochrane Central Register of Controlled Trials (CENTRAL), and Scopus	SR of 13 RCTs and 2 CCTs	Class I, II and III; crowding.	Piezocision	Conventional treatment	RCTs: 8 high risk; 1 low and 3 some concerns. CCTs: 2 serious.	Primary outcome: Canine retraction velocity and duration of the orthodontic treatment. Secondary outcome: loss of anchorage; root resorption; gingival index; patient's pain.	The low-quality evidence suggests that piezocision is an effective surgical procedure in accelerating orthodontic tooth movement, but this effect is clinically small and transient for the first three months according to bone remodeling. Moreover, no high quality RCTs with a large sample size have yet been done in order to

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Table 2 (continued)

Author, Year of publication	Search period	Databases	Study design; total n. of subjects	Diagnosis	Intervention	Control	Quality of the primary studies	Outcomes	Conclusions
Mota-Rodriguez et al., 2019 ^[39]	up to first months of 2019	PubMed, Cochrane, Scopus, Science Direct	SR of 31 studies; 618 subjects	Class I with crowding; Class II/1, Class II/2; bite; maxillary protrusion; ankylosis; maxillary Hypoplasia; impacted canines; super-eruption of molars	piezoelectric; conventional orthodontic surgery; MOP; osteotomy; alveolar distraction; interseptal reduction; accelerated osteogenic orthodontics conventional and modified corticotomy	NR	NR	Duration of orthodontic treatment	help in constructing a more solid scientific point of view regarding this intervention. The different techniques of accelerated orthodontics reduce the phase of hyalinization that delays dental movement, which has led to a better acceptance of the patient and the clinician.
Patterson et al., 2016 ^[40]	up to May 2015	MeDLINE, EMBASE, Cochrane Central Register of Controlled Trials (CENTRAL), SCOPUS and Web of Science Core Collection database	SR of 14 studies: 3 RCTs and 3 RCTs split-mouth; 4 CCTs and 4 CCTs split-mouth; 249 subjects	NR	orthodontics conventional and modified corticotomy	conventional orthodontics therapy	Overall low quality	RTM; Periodontal Parameters; Root Resorption; Tooth Vitality.	The available body of literature for corticotomy facilitated orthodontics currently provides a low quality of evidence to suggest that the corticotomy procedure results in an acceleration of orthodontic tooth movement. The included studies in the review process indicated a statistically important increase in the rate of tooth movement compared with control groups. When examined temporally, the acceleration of tooth movement appeared to last only in the short-term, with rates of movement returning close to baseline after a few months. Corticotomy-facilitated orthodontic procedures did not appear to increase the risk of adverse sequelae on the periodontium, tooth vitality, or root resorption process compared with normal orthodontic treatment
Shahabee et al., 2019 ^[41]	up to February 2019	MEDLINE via PubMed, ISI Web of Science core collection via a web of knowledge, EMBASE, Scopus, Cochrane central register of controlled trials via Cochrane library	SR of 6 studies: 4 RCTs split mouth and 2 RCT parallel arm; 192 subjects	Class I with bimaxillary protrusion; Class II/1; Class III	MOP	NR	1 low risk and 5 unclear	RTM; Root resorption; Pain.	The difference in the rate of canine retraction after performing the MOP was statistically significant but clinically not very substantial (0.45 mm increase in month). The patients did not report any significant differences in terms of the pain severity levels after MOP. With regard to the adverse effects after MOP, one study observed higher amounts of root resorption among patients undergoing MOP. The use of MOP can be recommended after weighing the

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Table 2 (continued)

Author, Year of publication	Search period	Databases	Study design; total n. of subjects	Diagnosis	Intervention	Control	Quality of the primary studies	Outcomes	Conclusions
Vannala, 2019 ^[42]	from January 2018 to August 2018	MEDLINE e EMBASE	SR of 23 RCT	Class I and Class II; Angle's Class I and Class II cases with first premolar extraction, Class III adult patients	PAOOT	NR	NR	Treatment time	benefits and disadvantages this intervention can bring for each patient. Periodontally accelerated osteogenic orthodontic treatment it helps to overcome many of the current limitations of conventional treatment, including lengthy duration, potential for periodontal complications, lack of growth, and the limited envelope of tooth movement. Randomized testing in humans is still necessary to confirm the claimed advantages of this technique and to evaluate the long-term effects of it
Viwattanati-pa et al., 2018 ^[43]	up to July 2017	PubMed, SCOPUS, Web of Science, Embase, and Cochrane Central Register of Controlled Trials (CENTRAL)	SR of 5 RCTs split mouth studies; 88 subjects	NR	Corticotomy piezocision	conventional orthodontic treatment	5 high risk	Primary outcomes: accumulative distance and velocity of tooth movement; Secondary outcomes: periodontal condition, root resorption and dehiscence, pain, discomfort and satisfaction	Corticotomy showed a more significant increase in the rate of tooth movement than did the conventional method. For piezocision, both accumulative tooth movement and rate of tooth movement were twice faster than those of the conventional method. Corticotomy (with a flap design) avoiding marginal bone incision) or flapless piezocision procedures were not detrimental to periodontal health. Nevertheless, piezocision resulted in higher levels of patient satisfaction. Weak evidence supports that piezocision is a safe adjunct to accelerate RTM and has no negative effects on periodontal health and pain perceptions, at least in the short term. The effects of piezocision on patient satisfaction root resorption and anchorage control are inconclusive.
Yi et al., 2017 ^[44]	Up to October 2016	PubMed, Cochrane Central Register of Controlled Trials (CENTRAL), Embase, China National Knowledge Infrastructure (CNKI), and System for Information on Grey Literature in Europe (SIGLE)	SR of 2 CCTs split mouth and 2 RCTs parallel-arm; 67 subjects	NR	piezocision	conventional orthodontic treatment	3 unclear risk of bias; 1 high risk.	RTM; periodontal parameters; root resorption; pocket depths; treatment satisfaction; anchorage control	piezocision resulted in higher levels of patient satisfaction. Weak evidence supports that piezocision is a safe adjunct to accelerate RTM and has no negative effects on periodontal health and pain perceptions, at least in the short term. The effects of piezocision on patient satisfaction root resorption and anchorage control are inconclusive.

SR, systematic review; MA, meta-analysis; CCT, controlled clinical trial; RCT, randomised controlled trial; NR, not reported; CAAOT, corticotomy accelerated osteogenic orthodontic treatment; PAAOT, periodontally accelerated osteogenic orthodontic treatment MOP; micro-osteoperforation; OTM, orthodontic tooth movement; RTM: rate of tooth movement; TOT: total orthodontic treatment time; OTT: orthodontic treatment time; OTT: orthodontic treatment time; PP: periodontal parameters; CTM: cumulative treatment time.

Table 3
Quality assessment of the included Systematic Review, according to the AMSTAR-2.

	Alfawal et al., 2016[17]	Al-Khalifa et al., 2020[18]	Apalimova et al., 2020[19]	Dab et al., 2018[20]	Darwiche et al., 2020[21]	Dos Santos et al., 2020[22]	Ferguson et al., 2018[23]	Fernandes-Ferrer et al., 2016[24]	Figuereido et al., 2019[25]	Fleming et al., 2015[26]	Fu et al., 2019[27]	Gil et al., 2017[28]	Gkantidis et al., 2014[29]	Hassan et al., 2015[30]		
Did the research questions and inclusion criteria for the review include the components of PICO?	Y	N	Y	N	N	Y	N	N	Y	Y	Y	N	Y	N	N	
Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol?	Y	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N
Did the review authors explain their selection of the study designs for inclusion in the review?	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Did the review authors use a comprehensive literature search strategy?	Y	PY	Y	Y	PY	Y	PY	Y	Y	Y	Y	Y	Y	Y	N	N
Did the review authors perform study selection in duplicate?	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Did the review authors perform data extraction in duplicate?	Y	N	N	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y
Did the review authors provide a list of excluded studies and justify the exclusions?	PY	N	N	PY	N	Y	N	PY	PY	Y	N	PY	PY	N	N	N
Did the review authors describe the included studies in adequate detail?	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	PY	Y	Y	Y	Y	Y
Did the review authors use a satisfactory technique for assessing the risk of bias (RoB) in individual studies that were included in the review?	Y	N	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Did the review authors report on the sources of funding for the studies included in the review?	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N

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Table 3 (continued)

Alfawal et al., 2016[17]	Al-Khalifa et al., 2020[18]	Apalimova et al., 2020[19]	Dab et al., 2018[20]	Darwiche et al., 2020[21]	Dos Santos et al., 2020[22]	Ferguson et al., 2018[23]	Fernandes-Ferrer et al., 2016[24]	Figuerido et al., 2019[25]	Fleming et al., 2015[26]	Fu et al., 2019[27]	Gil et al., 2017[28]	Gkantidis et al., 2014[29]	Hassan et al., 2015[30]
Y	Nm	Nm	Y	Nm	Y	Nm	Nm	Nm	Y	Y	Nm	Y	Nm
If meta-analysis was performed did the review authors use appropriate methods for statistical combination of results?													
Y	Nm	Nm	Y	Nm	Y	Nm	Nm	Nm	Y	Y	Nm	Y	Nm
If meta-analysis was performed did the review authors assess the potential impact of RoB in individual studies on the results of the meta-analysis or other evidence synthesis?													
Y	N	y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	PY
Did the review authors account for RoB in individual studies when interpreting/discussing the results of the review?													
Y	Y	y	Y	PY	Y	Y	Y	Y	Y	Y	Y	Y	PY
Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?													
Y	Nm	Nm	Y	Nm	Y	Nm	Nm	Nm	Y	Y	Nm	Y	Nm
If they performed quantitative synthesis did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review?													
Y	PY	y	PY	N	Y	Y	PY	Y	Y	Y	Y	Y	N
Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?													
H	CL	M	H	CL	H	CL	M	M	H	H	L	H	CL
Hoffman et al., 2017[31]	Hoogeven et al., 2014[32]	Kalemaj et al., 2015[33]	Kamal et al., 2019[34]	Khlef et al., 2019[35]	Long et al., 2013[36]	Macdonald et al., 2020[37]	Mheissen et al., 2019[38]	Mota-Rodriguez et al., 2019[39]	Patterson et al., 2016[40]	Shahabee et al., 2019[41]	Vannala et al., 2019[42]	Vivattananatipa et al., 2018[43]	Yi et al., 2017[44]

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Table 3 (continued)

	Alfawal et al., 2016[17]	Al-Khalifa et al., 2020[18]	Apalimova et al., 2020 [9]	Dab et al., 2018[20]	Darwiche et al., 2020[21]	Dos Santos et al., 2020[22]	Ferguson et al., 2018[23]	Fernandes-Ferrer et al., 2016[24]	Figuereido et al., 2019[25]	Fleming et al., 2015[26]	Fu et al., 2019[27]	Gil et al., 2017[28]	Gkantidis et al., 2014[29]	Hassan et al., 2015[30]
Did the research questions and inclusion criteria for the review include the components of PICO?	Y	N	Y	Y	Y	PY	Y	Y	N	Y	Y	N	Y	N
Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol?	Y	N	N	N	Y	N	N	N	N	N	N	N	N	N
Did the review authors explain their selection of the study designs for inclusion in the review?	Y	N	Y	N	Y	Y	Y	Y	N	Y	N	Y	Y	Y
Did the review authors use a comprehensive literature search strategy?	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	PY
Did the review authors perform study selection in duplicate?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y
Did the review authors perform data extraction in duplicate?	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y
Did the review authors provide a list of excluded studies and justify the exclusions?	Y	PY	PY	PY	PY	PY	PY	PY	PY	PY	PY	N	PY	PY
Did the review authors describe the included studies in adequate detail?	Y	Y	Y	Y	Y	Y	Y	Y	PY	Y	Y	N	Y	Y
Did the review authors use a satisfactory technique for assessing the risk of bias (RoB) in individual studies that were included in the review?	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y
Did the review authors report on the sources of funding for the studies included in the review?	N	N	N	N	N	N	N	N	N	N	N	N	N	N

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Table 3 (continued)

	Alfawal et al., 2016[17]	Al-Khalifa et al., 2020[18]	Apalimova et al., 2020[19]	Dabet al., 2018[20]	Darwiche et al., 2020[21]	Dos Santos et al., 2020[22]	Ferguson et al., 2018[23]	Fernandes-Ferrer et al., 2016[24]	Figuereido et al., 2019[25]	Fleming et al., 2015[26]	Fu et al., 2019[27]	Gil et al., 2017[28]	Gkantidis et al., 2014[29]	Hassan et al., 2015[30]
If meta-analysis was performed did the review authors use appropriate methods for statistical combination of results?	Nm	Nm	Nm	Y	Y	Nm	Y	Y	Nm	Nm	Y	Nm	Nm	Nm
If meta-analysis was performed did the review authors assess the potential impact of RoB in individual studies on the results of the meta-analysis or other evidence synthesis?	Nm	Nm	Nm	Y	Nm	Y	Y	Y	Nm	Nm	Y	Nm	Nm	Nm
Did the review authors account for RoB in individual studies when interpreting/discussing the results of the review?	Y	PY	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y
Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?	Y	PY	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y
If they performed quantitative synthesis did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review?	Nm	Nm	Nm	Y	Nm	Y	Y	Y	Nm	Nm	Y	N	Nm	Nm
Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?	PY	N	PY	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	PY
OVERALL QUALITY ASSESSMENT	M	CL	M	H	H	H	H	H	CL	M	H	CL	M	M

Following piezocision, Mheissen and co-workers reported that canine retraction rate in the first and second month was 0.66 mm/month and 0.48 mm/month, respectively, and the total canine retraction rate in the first two months was significantly reduced as compared to the conventional treatment (0.57 mm/month, $p < 0.001$) [38]. Similarly, Alpimova and co-authors supported an increase the rate of dental movement during the first months, however the observed a return to baseline values in the following months. [19] Viwattanatipa and colleagues also reported positive findings regarding short-term acceleration of OTM following piezocision in the short term, but the level of evidence provided to support these results was weak [43].

With regards to total treatment time, Mheissen and co-workers reported statistically significant difference in the overall treatment time (MD 101.64 Days) in the piezocision group compared to conventional treatment. However, the authors underlined that these findings were supported by low quality evidence, and the clinically significance of those findings was considered questionable [38]. Figueiredo and colleagues showed contradictory results on the effects of piezocision and lacked to find high-quality evidence [25]. Similarly, also Hoffmann and co-workers pointed out that the extent of the acceleration was inconsistent using piezocision [31]. Finally, authors of three included SRs concluded that efficacy of piezocision in acceleration of orthodontic tooth movement could not be reported due to low-quality evidence. [17,27,37].

3.4.4. Micro-osteoperforations (MOPs)

MOP was addressed in 9 SRs [17,18,22,23,27,31,37,39,41], and it was generally described as a procedure in which small pinhole perforations are created in the bone around the teeth to be orthodontically displaced. Dos Santos and co-workers, observed no differences between conventional method and MOP, related to rate of canine retraction or total anterior retraction per month [22]. Similarly, also Fu and colleagues found no accelerated tooth movement in the MOP group [27]. Authors from other SRs conclude that the evidence was too weak to support the role of MOP in the acceleration of orthodontic tooth movement [17,31,37,39]. On the contrary, Shahabee and co-workers found that the rate of canine retraction per month was significantly higher in the MOP group [mean difference (MD) = 0.45 mm] as compared to conventional group [41], and also Al-Khalifa and colleagues concluded that MOP was an effective method of accelerating tooth movement [18].

4. Discussion

The currently available literature demonstrated conflicting conclusions regarding the adjunctive interventions for accelerating orthodontic treatment time. Thus, the present study aimed to collect and rate the scientific evidence provided by SRs on the effect of surgical procedures in the acceleration of orthodontic tooth movement and to assess the methodological quality of the published SR. The present overview identified 28 SRs that addressed different surgical techniques: corticotomy, piezocision and micro-osteoperforations.

The idea of surgical acceleration came after the introduction of regional acceleratory phenomenon (RAP) by Frost in 1989 [45]. RAP phenomenon was studied predominately in animals' models and in in-vitro studies, and it has been described as a tissue reaction to a noxious stimulus that increases the healing capacities of the affected tissues [46]. It appears that the size of the affected region and the intensity of its response varies directly with the magnitude of that stimulus, although to different degrees in different individuals. RAP is characterized by acceleration of the normal cellular activities. Indeed, increased osteoclast activity was found on the compression side while osteogenic markers were found on the tension side of the tooth movement [47]. Indeed, elevated catabolic bone biomarkers

(tumour necrosis factor- α , TNF- α and tartrate-resistant acid phosphatase-TRAP) were observed during 2 or 3 weeks immediately following surgical acceleration techniques [23].

The majority of the included SRs provided positive findings with regards to corticotomy, that seemed to consistently accelerate the orthodontic tooth movement. However, different surgical techniques and instruments were used in the primary studies included in each review. For instance, in the study of Long and co-workers, corticotomy was studied as small perforations on the alveolar bones along the way by which the tooth would be moved, whereas other SRs summarized results from mandibular and maxillary corticotomy made by piezosurgical microsaw or conventional instruments [21]. Also, number, length, and depth of cortical bone incisions were different among studies and this might influence the acceleration of the movement and the postoperative sequelae. Hence, the heterogeneity among techniques contributes to make the results less conclusive.

A modification of corticotomy with or without alveolar bone grafting has been referred to as corticotomy-accelerated osteogenic orthodontic treatment (CAOOT) and more recently to as "periodontally accelerated osteogenic orthodontics" (PAOO). PAOO is a combination of periodontal and orthodontic treatment, which includes corticotomy followed by bone graft and orthodontic treatment. In the included SRs different bone grafts were used to augment the bone thickness and density in adjunct to corticotomy like allograft, bovine bone or bioactive glass graft. The grafts differ considerably as embryology, histology, mechanical properties and rate of resorption concerned [48,49], so it may influence the bone density, bone thickness and periodontal parameters evaluated in the included studies. Moreover, these surgical techniques are technical-demanding and require expert surgeons [50]. The assessment of bone density before and after the abovementioned surgical procedures was evaluated with different radiographic methods. Although mild improvements in alveolar bone density and thickness were detected, these findings were confounded by the use of particulate bone allograft, which made difficult to assess the true effect of the surgical procedure on alveolar bone parameters.

Some studies have also reported that procedures involving full-thickness flap elevation could cause periodontal problems and increase tooth mobility and bone dehiscence [51]. In this regard, a recent article pointed out clinical benefits in terms of minimizing gingival recession when a vestibular incision subperiosteal tunnel access (VISTA) was used [52].

Although the abovementioned techniques reduce the side effects of the prolonged orthodontic treatments, some noteworthy complications need to be reported during or after the surgical procedures, like pain, swelling, temporary paraesthesia etc. Above all instruments used, the piezoelectric osteotomy reduces the degree of inflammation, pain, swelling, and morbidity, improving satisfaction and patient comfort [53]. The AMSTAR scale is a validated tool for the methodological quality assessment of SRs [16]. AMSTAR-2 was developed to enable the appraisal of SRs of randomised and non-randomised studies of healthcare interventions. The AMSTAR-2 is composed by 16 items in total (compared with 11 in the original), and the overall rating is based on weaknesses in critical domains which may greatly affect the confidence on the results provided by a SR. In this overview, the methodological quality of the included reviews ranged between critically low (6 studies) and high (12 studies), indicating a moderate overall quality. The most common critical weakness was the absence of clearly a-prior established review methods and any significant deviations from the protocol. In particular, the presence of an "a priori" review methods refers to the registration of the review protocol, before the commencement of the review, using international dedicated online databases such as PROSPERO (International Prospective Register of Ongoing Systematic Reviews). The protocol registration allows transparency in the

review process and show adherence to pre-determined review methods. However, many SR failed to perform registration since they were published before protocol databases had been launched [54].

The findings of the current study should be understood in the light of its important limitations. Although a comprehensive search strategy was employed and complemented through extensive manual cross-reference searching for identification of all relevant articles, it may still be possible that some grey literature was missed. Additionally, it should be noted that most of the current literature reported relatively short-term results, as reflected by the average follow-up time of 3 months.

Conclusions

The current overview of SR highlighted that the quality level of the published SRs focusing on the topic of surgical procedures in orthodontic tooth movement acceleration was extremely variable, thus ranging from low to high. Therefore, it is crucial for clinicians and researchers to be familiar with the dedicated tools to appraise the quality of the available literature, to access the best level of evidence.

According to the results provided by currently published SRs, favourable consistent findings regarding corticotomy can be found, in terms of both orthodontic treatment length and tooth movement rate, as compared to conventional treatment. On the other hand, with regards to the other studied surgical approaches (piezocision, micro-osteoperforation and cortico/piezocision with graft) conflicting results arise from the currently published SR, thus preventing from supporting or discouraging the use of those techniques for the acceleration of the orthodontic tooth movement.

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Conflicts of Interest

The authors declare that they have no conflict of interest.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jdsr.2022.03.003.

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