Review

Pain and root resorption due to surgical interventions to accelerate tooth movement in orthodontics: A systematic review and meta-analysis

Mariano Ortiz-Pizarro[1,A–F], Marcos Jimmy Carruitero-Honores[2,3,C–F], Silvio Augusto Bellini-Pereira[4,D–F], Aron Aliaga-Del Castillo[4,D–F]

[1] School of Medicine, César Vallejo University, Trujillo, Peru
[2] Faculty of Medicine, Antenor Orrego Private University, Trujillo, Peru
[3] School of Dentistry, Santo Toribio de Mogrovejo Catholic University, Chiclayo, Peru
[4] Department of Orthodontics and Pediatric Dentistry, School of Dentistry, University of Michigan, Ann Arbor, USA

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl*. 2024;61(3):427–438

Address for correspondence
Mariano Ortiz-Pizarro
E-mail: mortizpi12@ucvvirtual.edu.pe

Funding sources
None declared

Conflict of interest
None declared

Acknowledgements
None declared

Received on December 21, 2022
Reviewed on February 5, 2023
Accepted on February 22, 2023

Published online on June 30, 2024

Abstract

Background. There are several publications that show the efficacy of surgical interventions in accelerating the rate of tooth movement in orthodontics. Consequently, possible adverse effects must also be evaluated.

Objectives. The aim of the present study was to compare the perception of pain and root resorption between orthodontic treatment with a surgical acceleration intervention vs. conventional orthodontic treatment.

Material and methods. An electronic search was conducted in the MEDLINE, Scopus, Web of Science (WoS), ScienceDirect, Cochrane Library, and Virtual Health Library (VHL) databases up to September 12, 2022. Randomized or non-randomized, controlled, parallel-arm or split-mouth clinical trials were included. Fixed-and random-effects meta-analyses were performed with regard to heterogeneity. The risk of bias (RoB) was assessed using the RoB 2.0 and ROBINS-I tools.

Results. A total of 1,395 articles were initially retrieved, 40 studies were finally included in the review and 15 studies were eligible for quantitative analysis. The meta-analysis showed a significant difference in pain perception between acceleration surgery vs. conventional orthodontics at 24 h ($p = 0.040$); however, this difference was not significant at 7 days ($p = 0.080$). Overall, the patients who underwent any acceleration procedure presented significantly less resorption as compared to those who were applied conventional treatment ($p < 0.001$). A similar significant difference was found in retraction movements ($p < 0.001$) and alignment movements ($p = 0.030$).

Conclusions. In the first 24 h, surgical interventions for the acceleration of tooth movement produce a greater perception of pain as compared to conventional orthodontic treatment, but the perception is similar after 7 days. Acceleration surgery results in less root resorption – in alignment movements, and especially in retraction movements.

Keywords: pain, acceleration, orthodontic tooth movement, root resorption, oral surgical procedures

Cite as
Ortiz-Pizarro M, Carruitero-Honores MJ, Bellini-Pereira SA, Aliaga-Del Castillo A. Pain and root resorption due to surgical interventions to accelerate tooth movement in orthodontics: A systematic review and meta-analysis. *Dent Med Probl*. 2024;61(3):427–438. doi:10.17219/dmp/161553

DOI
10.17219/dmp/161553

Introduction

In recent years, techniques for accelerating tooth movement in orthodontics have been demonstrated, and they have become an interesting option for adult patients who require fixed orthodontic treatment, but within a shorter period.[1–4] In general, acceleration interventions initiate a regional inflammatory process with temporary osteopenia due to increased osteoclastic activity, enabling the reduction of bone resistance with respect to tooth movement.[2,3] Surgical interventions may include techniques such as corticotomy – with or without laser, piezocision, discision, corticision, piezopuncture, and micro-osteoperforation.[4,5]

Ideally, this approach should allow clinicians to control both the level and location of inflammation, preventing negative side effects as much as possible.[5] However, it has also been established that the inflammatory mechanisms necessary to generate tooth movement share some characteristics with inflammatory processes that are not favorable for tissue integrity.[6–8]

Recently, a significant number of publications have reported evidence of the effect of surgical acceleration interventions in orthodontic treatment, showing favorable results with respect to the amount and rate of movement.[8–13] There are fewer and fewer clinical trials that evaluate, under a certain methodology, the adverse effects due to the inflammatory mechanisms of an acceleration intervention.[8–10] The perception of pain and root resorption are 2 important outcomes in terms of patient acceptance and long-term success of the intervention,[4,9] but there are very few systematic reviews that quantitatively report on these unfavorable outcomes,[9,13] making more studies necessary to be able to reach a consensus on the safety of acceleration interventions.

Therefore, the purpose of this systematic review was to summarize and analyze the available evidence regarding the effect of surgical interventions to accelerate tooth movement with respect to pain perception and root resorption as compared to conventional treatment.

Material and methods

This review followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines.[14] The focused question was: "Do surgical interventions to accelerate tooth movement produce a similar perception of pain and root resorption as compared to conventional orthodontic treatment?"

The inclusion criteria were established according to the PICO strategy. The population comprised adult and adolescent patients undergoing orthodontic treatment (P). Surgical techniques for tooth movement acceleration were considered as interventions (I). Conventional orthodontic treatment was considered the comparison (C). The outcomes were pain perception and root resorption (O).

Inclusion criteria

The inclusion criteria were as follows:

- clinical trials comparing a surgical intervention to accelerate tooth movement with conventional orthodontic treatment;
- clinical trials with the following outcomes evaluated – perception of pain or root resorption;
- randomized or non-randomized, controlled, parallel-arm or split-mouth clinical trials; and
- clinical trials in any language and without restrictions regarding the publication time.

Exclusion criteria

The exclusion criteria were as follows:

- clinical trials using more than one surgical acceleration intervention, an additional surgical technique or bone grafting in the experimental group;
- clinical trials using some surgical procedure in the comparison group;
- clinical trials with acceleration surgeries provided together with orthopedic or functional treatment; and
- observational studies, animal studies, case reports, books, editorials, and expert opinions.

Search strategy

An electronic literature search was carried out by 2 independent reviewers (M.O.P and M.J.C.H.), using the following databases: MEDLINE (via PubMed), Scopus, Web of Science (WoS), ScienceDirect, Cochrane Library, and Virtual Health Library (VHL). Handsearching was performed in other sources, such as Google Scholar to identify unpublished articles, orthodontic journals with an impact factor greater than 1, and through the reference list of each retrieved article. This review also shows the results of a supplemental search of gray literature through OpenGray and MedRxiv. The general search expression was as follows: (rapid* OR accelerat* OR speed*) AND ("tooth movement" OR orthod*) AND ("root resorption" OR "orthodontic resorption" OR "pain" OR "visual analog scale"). The search strategy used was modified according to the search syntax in each database. The literature search was performed without time restrictions, and the last date of the search was September 12, 2022.

Data collection

After the removal of duplicates, 2 independent reviewers (M.O.P and M.J.C.H.) selected the remaining articles in 2 phases. In the 1st phase, both reviewers examined the studies by title and abstract to determine retrieved articles that met the inclusion criteria. In case of disagreement, a decision was made by consensus through the participation of a third evaluator (S.A.B.P.), and then the articles were incorporated. In the 2nd phase, the same reviewers performed a full-text evaluation of the pre-selected articles to determine their eligibility and proceed to data extraction.

Data extraction

Two independent reviewers (M.O.P and M.J.C.H.) extracted the information from the included articles using a standardized Microsoft Excel spreadsheet. The following data was extracted: title; first author; year of publication; study design; sample size; dental groups; gender and age of the participants; characteristics of the malocclusion; mechanics of movement and the applied force; type and details of the intervention; and characteristics of the evaluated outcomes (definition, measurement instrument, unit of measurement, and follow-up time). Any discrepancies or disagreement were resolved through the participation of a third investigator (S.A.B.P.).

Risk of bias

The risk of bias (RoB) assessment of the included studies was carried out using different tools depending on the study design. For randomized clinical trials (RCTs), the RoB 2.0 tool[15] of the Cochrane Collaboration was used, allowing the studies to be classified as being of low RoB, some concerns or high RoB. The ROBINS-I tool[16] was used to evaluate non-randomized studies (NRSs), allowing the studies to be classified into low, moderate, serious, critical RoB, or no information categories. Again, the RoB assessment was performed independently by 2 reviewers (M.O.P and M.J.C.H.), and any disagreement was resolved through discussion with a third author (S.A.B.P.).

Statistical analysis

The primary outcome was pain perception and the secondary outcome was root resorption. Quantitative data from studies with similar measurement methodologies and follow-up time for outcomes were pooled. For the perception of pain, a measurement interval of 24 h was considered for scales from 1 to 10, and 7 days for scales from 1 to 100, while the evaluation of root resorption was considered in linear millimeters, with a minimum follow-up period of 3 months, and according to tooth movements of alignment or retraction.

A meta-analysis was performed using a computer program (RevMan, v. 5.4), and the extracted data was expressed as continuous variables. The mean and standard deviation ($M \pm SD$) with a 95% confidence interval (*CI*) were used to estimate the treatment effect. Statistical significance for the hypothesis test was established at $p < 0.05$. A random-effects model was considered, while heterogeneity between the studies was estimated based on the χ^2, τ and I^2 statistics.

Results

The electronic search of the databases identified 1,310 articles published up to September 12, 2022. According to the established protocol, additional 85 articles were manually identified from other sources. Duplicate records were eliminated, and the remaining 997 studies were screened by title and abstract, with 834 records being excluded and 163 full-text articles reviewed for eligibility. Finally, after applying the exclusion criteria, 40 studies were included in the qualitative synthesis of the systematic review and 15 studies in the quantitative synthesis (Fig. 1).

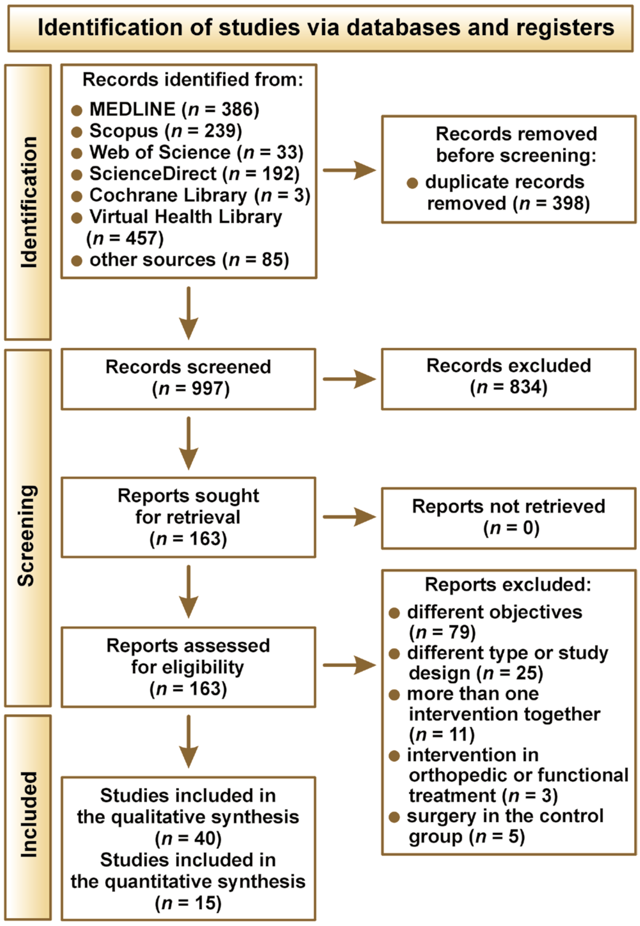


Fig. 1. Flowchart of the study according to the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines

Study characteristics

Table 1 summarizes the main features of all included studies that evaluated treatment assisted by acceleration surgery vs. conventional orthodontic treatment.[1,2,17–54] Of the 40 included studies, 33 studies were RCTs,[18–20,22,25–34,36–54] of which 15 had a parallel-arm design[18,28–30,34,36,41,44,45,47,48,50,51,53,54] and 18 used a split-mouth design.[19,20,22,25–27,31–33,37–40,42,43,46,49,52] Likewise, 7 studies were NRSs,[1,2,17,21,23,24,35] of which 2 had a parallel-arm design[1,17] and 5 used a split-mouth design.[2,21,23,24,35]

Table 1. Characteristics of the included studies

Author, year	Study design	Groups (*n*)	Gender	Age [years]	Malocclusion/ treatment plan	Acceleration intervention	Mechanics of movement	Evaluation/ follow-up by outcome	Outcomes (statistical significance)	
									pain	root resorption
Yavuz et al.[1] 2018	NRS parallel-arm	GPZO: 9 GDC:12 GC: 14	35F	GPZO: 13–18 GDC: 13–18 GC: 13–19	Class I with crowding/ without extractions	PZO DC	upper and lower alignment, self-ligating brackets	pain: VAS NR/30 days resorption: panoramic X-ray/complete alignment	no quantitative comparison data	the difference between GPZO/GDC and GC was NS
Omidkhoda et al.[2] 2020	NRS split-mouth	GPZp: 17 GC:17	7M/10F	18.23 ±1.35	Class I and II-1/ bilateral extraction of maxillary 1PM	PZp	canine retraction, 150 grf, non-self-ligating brackets	pain: VAS 0–10/2 months resorption: –	the difference between GPZp and GC was NS	none
Shoreibah et al.[17] 2012	NRS parallel-arm	GCT: 10 GC: 10	4M/16F	18.4–25.6	Class I, with a discrepancy of 3–5 mm/ without extractions	CT	lower anterior alignment	pain: – resorption: periapical X-ray (mm)/6 months post-treatment	none	the difference between GCT and GC was NS
Alikhani et al.[18] 2013	RCT parallel-arm	GMOP: 10 GC:10	GMOP: 5M/5F GC: 3M/7F	GMOP: 26.8 GC: 24.7	Class II-1/ extraction of maxillary 1PM	MOP	canine retraction, 100 grf	pain: rating scale 0–10/28 days resorption: –	the difference between GMOP and GC was NS	none
Al-Naoum et al.[19] 2014	RCT split-mouth	GCT: 30 GC: 30	15M/15M	20.04 ±3.63	Class II-1 and II-2/ extraction of maxillary 1PM	CT	canine retraction, 120 grf, non-self-ligating brackets	pain: Likert scale 1–4/7 days resorption: –	no quantitative comparison data	none
Abbas et al.[20] 2016	RCT split-mouth	GPZO: 10 GCT: 10 GC: 20	NR	15–25	Class II-1/ bilateral extraction of maxillary 1PM	PZO CT	canine retraction, 150 grf, non-self-ligating brackets	pain: – resorption: CBCT (mm)/3 months	none	GC > GPZO and GCT
Patterson et al.[21] 2017	NRS split-mouth	GPZO: 14 GC: 14	6M/8F	16.17	NR/ bilateral extraction of maxillary 1PM	PZO	tipping forces in 1PM with 150 grf, self-ligating brackets	pain: – resorption: CBCT (mm^3)/28 days	none	GPZO > GC
Chan et al.[23] 2018	NRS split-mouth	GMOP: 20 GC: 20	8M/12F	15.4	malocclusion with crowding on each side of the maxilla/ extraction of 1PM	MOP	tipping forces in 1PM with 150 grf	pain: – resorption: CBCT (mm^3)/28 days	none	GMOP showed 48% higher resorption than GC
Elkalza et al.[24] 2018	NRS split-mouth	GMOP: 8 GPZO: 8 GC: 16	NR	16–25	NR/ extraction of maxillary 1PM	MOP PZO	canine retraction, 150 grf, self-ligating brackets	pain: – resorption: CBCT (mm^3)/ complete retraction	none	the difference between GMOP and GC was NS GPZO > GC
Sivarajan et al.[25] 2019	RCT split-mouth	GMOP: 30 GC: 30	7M/23F	22.2 ±3.72	NR/ extraction of the first 4 PMs	MOP	canine retraction 140–200 grf, non-self-ligating brackets	pain: Likert scale 1–5/16 weeks resorption: –	GMOP > GC	none
Aboalnaga et al.[26] 2019	RCT split-mouth	GMOP: 18 GC: 18	0M/18F	20.50 ±3.85	NR/ bilateral extraction of maxillary 1PM	MOP	canine retraction, 150 grf, non-self-ligating brackets	pain: rating scale 1–10/7 days resorption: CBCT (mm^3) – Malmgren index 0–2/4 months	69% responded GMOP > GC	the difference between GMOP and GC was NS
Alqadasi et al.[27] 2019	RCT split-mouth	GMOP: 8 GC: 8	NR	15–40	Class II-1/ extraction of maxillary 1PM	MOP	canine retraction, 150 grf, self-ligating brackets	pain: rating scale 0–10/28 days resorption: CBCT (mm)/3 months	GMOP and GC had equal percentages of pain	the difference between GMOP and GC was NS
Bansal et al.[28] 2019	RCT parallel-arm	GMOP: 15 GC: 15	GMOP: 7M/8F GC: 7M/8F	GMOP: 15.87 ±1.72 GC: 15.33 ±1.17	malocclusion with the irregularity index of 4–6 mm/ without extractions	MOP	antero-inferior alignment, non-self-ligating brackets	pain: VAS 0–100/7 days resorption: CBCT (mm^3)/6 months	GMOP > GC at T0	the difference between GMOP and GC was NS

Author, year	Study design	Groups (*n*)	Gender	Age [years]	Malocclusion/ treatment plan	Acceleration intervention	Mechanics of movement	Evaluation/ follow-up by outcome	Outcomes (statistical significance)	
									pain	root resorption
Charavet et al.[29] 2019	RCT parallel-arm	GPZO: 12 GC: 12	GPZO: 5M/7F GC: 4M/8F	GPZO: 34 ±8 GC: 27 ±7	malocclusion with mild or moderate bimaxillary crowding/ without extractions	PZO	upper and lower alignment, self-ligating brackets	pain: VAS 0–10/7 days resorption: CBCT (mm)/ complete alignment	GPZO > GC	the difference between GPZO and GC was NS
Gibreal et al.[30] 2019	RCT parallel-arm	GPZO: 16 GC: 16	GPZO: 6M/10F GC: 7M/9F	GPZO: 20.86 ±1.90 GC: 21.27 ±1.87	Class II-1 with anterior inferior crowding/ extraction of maxillary 1PM	PZO	antero-inferior incisor alignment, self-ligating brackets	pain: VAS 0–100/28 days resorption: –	the difference between GPZO and GC was NS	none
Alfawal et al.[31] 2020	RCT split-mouth	GPZO: 16 GCTLz: 16 GC: 16	GPZO: 7M/9F GCTLz: 6M/10F	GPZO: 18.06 ±2.79 GCTLz: 18.44 ±3.38	Class II-1/ bilateral extraction of maxillary 1PM	PZO CTLz	canine retraction, 150 grf, non-self-ligating brackets	pain: rating scale 0–10/7 days resorption: –	GPZO and GCTLz > GC at T1	none
Babanouri et al.[32] 2020	RCT split-mouth	GMOP: 25 GC: 25	11M/14F	15–45	Class I and II-1 with biprotrusion/ extraction of maxillary 1PM	MOP	canine retraction, 150 grf, non-self-ligating brackets	pain: VAS 0–10/2 days resorption: –	the difference between GMOP and GC was NS	none
Gulduren et al.[33] 2020	RCT split-mouth	GMOP: 9 GC: 9	5M/4F	GMOP: 21.8 GC: 17.7	Class I–II/ without extractions	MOP	superior molar distalization, 500 grf/frictionless	pain: VAS 0–10/20 days resorption: –	the difference between GMOP and GC was NS	none
Hatrom et al.[34] 2020	RCT parallel-arm	GPZO: 12 GC: 11	GPZO: 6M/6F GC: 5M/6F	GPZO: 19.8 ±3.1 GC: 20.4 ±4.1	Class II-1/ bilateral extraction of maxillary 1PM	PZO	en-mass retraction, 250 grf, non-self-ligating brackets	pain: rating scale 0–10/2 days resorption: CBCT (mm)/4 months	GPZO > GC at T0	GPZO < GC in central incisors and right canine
Ibrahim et al.[35] 2020	NRS split-mouth	GPZO: 10 GC: 10	NR	15–19	Class I and II-1/ bilateral extraction of maxillary 1PM	PZO	canine retraction, 150 grf, non-self-ligating brackets	pain: – resorption: CBCT (mm^3)/complete retraction	none	the difference between GPZO and GC was NS
Kundi et al.[36] 2020	RCT parallel-arm	GMOP: 15 GC: 15	14M/16F	GMOP: 27.5 ±4.4 GC: 28.4 ±4.5	Class II-1/ bilateral extraction of maxillary 1PM	MOP	canine retraction, 100 grf, non-self-ligating brackets	pain: rating scale 0–10/7 days resorption: –	GMOP > GC at T1 and T2	none
Mahmoudzadeh et al.[37] 2020	RCT split-mouth	GCTLz: 12 GC: 12	3M/9F	18.91 ±3.87	NR/ bilateral extraction of maxillary 1PM	CTLz	canine retraction, 150 grf, non-self-ligating brackets	pain: VAS 0–10/7 days resorption: –	the difference between GCTLz and GC was NS	none
Raj et al.[38] 2020	RCT split-mouth	GPZO: 20 GC: 20	6M/14F	23.18 ±1.41	Class II-1/ bilateral extraction of maxillary 1PM	PZO	canine retraction, 150 grf, non-self-ligating brackets	pain: – resorption: CBCT (mm)/6 months	none	the difference between GPZO and GC was NS
Alqadasi et al.[39] 2021	RCT split-mouth	GMOP: 10 GPZO: 11 GC: 21	GMOP: 4M/6F GPZO: 5M/6F	20.89 ± 4.46	Class II-1/ bilateral extraction of maxillary PMs	MOP PZO	canine retraction, 150 grf, non-self-ligating brackets	pain: – resorption: CBCT (mm)/3 months	none	the difference between GMOP/ GPZO and GC was NS
Jaber et al.[40] 2021	RCT split-mouth	GCTLz: 18 GC: 18	7M/11F	16.9 ±2.5	Class II-1/ bilateral extraction of maxillary 1PM	CTLz	canine retraction, 150 grf, non-self-ligating brackets	pain: Likert scale 1–4/7 days resorption: –	the difference between GCTLz and GC was NS	none
Ozkan and Arici41 2021	RCT parallel-arm	GMOP: 12 GC: 12	GMOP: 6M/6F GC: 6M/6F	GMOP: 17.27 ±1.20 GC: 18.13 ±1.20	Class I and II-1/ bilateral extraction of maxillary 1PM	MOP	canine retraction, 150 grf, non-self-ligating brackets	pain: VAS 0–100/1 day resorption: –	increased in both groups/ no quantitative comparison data	none
Ravi et al.[42] 2021	RCT split-mouth	GPZO: 15 GC: 15	NR	18–26	NR/ bilateral extraction of maxillary 1PM	PZO	canine retraction, 150 grf, non-self-ligating brackets	pain: – resorption: CBCT (mm)/3 months	none	the difference between GPZO and GC was NS
Raza et al.[43] 2021	RCT split-mouth	GCT: 10 GC: 10	mostly women, number NR	15–25	NR/ bilateral extraction of maxillary 1PM	CT	canine retraction, 150 grf, non-self-ligating brackets	pain: VAS 0–100/24 h and 7 days resorption: CBCT (mm)/complete retraction	24 h: GCT > GC 7 days: NS	GC > GCT

Author, year	Study design	Groups (*n*)	Gender	Age [years]	Malocclusion/ treatment plan	Acceleration intervention	Mechanics of movement	Evaluation/ follow-up by outcome	Outcomes (statistical significance)	
									pain	root resorption
Shahrin et al.[44] 2021	RCT parallel-arm	GMOP: 14 GC: 14	5M/25F	22.66 ± 3.27	crowding with adiscrepancy of 5–8 mm/ extraction of 1PM	MOP	alignment and leveling of maxillary incisors	pain: – resorption: periapical X-ray (mm)/6 months	none	the difference between GMOP and GC was NS
Sirri et al.[45] 2021	RCT parallel-arm	GCTC: 26 GC: 26	14M/38F	GCTC: 21.30 ±1.49 GC: 21.46 ±1.76	crowding with the irregularity index of 2–6 mm/ without extractions	CTC	lower anterior alignment and leveling	pain: – resorption: CBCT (mm)/ complete alignment and leveling	none	the difference between GCTC and GC was NS
Thomas et al.[46] 2021	RCT split-mouth	GMOP: 33 GC: 33	9M/24F	22.10 ±2.19	Class I and II-1/ bilateral extraction of maxillary 1PM	MOP	canine retraction, 150 grf, non-self-ligating brackets	pain: – resorption: CBCT (mm)/3 months	none	the difference between GMOP and GC was NS
Alkasaby et al.[47] 2022	RCT parallel-arm	GMOP: 10 GC: 10	20F	GMOP: 18.1 ±1.2 GC: 18.0 ±1.1	space deficiency in the upper arch 5–8 mm/ without extractions	MOP	distalization of first molars by Fast Back/ 300 grf, frictionless	pain: – resorption: CBCT (mm)/ complete distalization	none	GMOP > GC (mesiobuccal roots)/ GC > GMOP (disto-buccal roots)
Arana et al.[48] 2022	RCT parallel-arm	GPZO: 7 GC: 8	mostly men, number NR	GPZO: 21.29 ±4.50 GC: 24.00 ±6.07	Class I, II or III with moderate irregularity/ without extractions	PZO	lower anterior alignment and leveling, self-ligating brackets	pain: – resorption: CBCT (mm)/ complete alignment and leveling	none	the difference between GPZO and GC was NS
Hawkins et al.[49] 2022	RCT split-mouth	GPZO: 20 GC: 20	8M/12F	18.70 ±1.12	crowding requiring the extraction of maxillary first PMs	PZO	canine retraction, 150 grf, self-ligating brackets	pain: VAS 0–100/0, 7 and 14 days resorption: –	GPZO had more pain but it was decreasing/ no comparison data	none
Al-Ibrahim et al.[50] 2022	RCT parallel-arm	GPZO: 22 GC: 22	GPZO: 4M/18F GC: 5M/17F	GPZO: 19.17 ±2.59 GC: 20.48 ±2.84	Class I with severe crowding(>6 mm)/ with extraction of maxillary first PMs	PZO	upper anterior alignment and leveling, self-ligating brackets	pain: VAS 0–100/1, 3 and 7 days resorption: –	1,3 and 7 days: GPZO > GC	none
Kumar et al.[51] 2024	RCT parallel-arm	GMOP: 10 GC: 10	GMOP: 4M/6F GC: 3M/7F	GMOP: 19.50 ±2.67 GC: 20.30 ±2.23	Class I protrusion or crowding/ with extraction of first PMs	MOP	retraction of maxillary and mandibular anterior teeth	pain: VAS 0–10/1, 7 and 14 days resorption: –	GMOP: a significant gradual decrease/ no comparison data	none
Li et al.[52] 2022	RCT split-mouth	GMOP: 20 GC: 20	NR	NR	NR/ bilateral extraction of maxillary 1PM	MOP	canine retraction, 150 grf, non-self-ligating brackets	pain: VAS 0–10 resorption: –	GMOP: a gradual decrease/ no comparison data	none
Sirri et al.[53] 2022	RCT parallel-arm	GCTC: 26 GC: 26	14M/38F	21.38 ± 1.05	crowding with the irregularity index of 2–6 mm/ without extractions	CTC	lower anterior alignment and leveling	pain: VAS 0–100/1, 7 and 14 days resorption: –	the difference between GCTC and GC was NS	none
Sultana et al.[54] 2022	RCT parallel-arm	GPZO: 6 GC: 7	GPZO: 0M/6F GC: 1M/6F	GPZO: 20.83 ±2.32 GC: 21.14 ±2.97	severe crowding requiring the extraction of maxillary first PMs	PZO	alignment and leveling of maxillary incisors	pain: VAS 0–10/0 and 7 days resorption: –	GPZO: post-operative pain was mild/ no comparison data	none

RCT – randomized clinical trial; NRS – non-randomized study; G – group; C – control; MOP – micro-osteoperforation; PZO – piezocision; CT – corticotomy; CTLz – laser corticotomy; CTC – corticision; DC – discision; PZp – piezopuncture; M – male; F – female; PM – premolar; VAS – visual analog scale; CBCT – cone-beam computed tomography; T – follow-up time; >/< – significantly higher/lower; NS – statistically non-significant; NR – not reported.

Within the surgical acceleration techniques, 18 studies used micro-osteoperforation in 299 patients,[18,22–28,32,33,36,39,41,44,46,47,51,52] 16 studies used piezocision in 208 patients,[1,20,21,24,29–31,34,35,38,39,42,48–50,54] 3 studies used laser corticotomy in 46 patients,[31,37,40] 3 studies used traditional corticotomy in 50 patients,[17,19,43] 2 studies used corticision in 52 patients,[45,53] 1 study used discision in 12 patients,[1] and another study performed piezopuncture in 17 patients.[2]

Overall, across all the included studies, 26 studies assessed pain perception,[1,2,18,19,22,25–34,36,37,40,41,43,49–54] and 22 studies assessed root resorption.[1,17,20–24,26–29,34,35,38,39,42–48]

Risk of bias within the studies

Regarding RCTs, 16 studies were classified as low risk,[22,25,26,28,30–32,36,37,39,40,44–47,53] 6 were evaluated with some concerns[33,34,41,43,50,52] and 11 studies were classified as high risk of bias[18–20,27,29,38,42,48,49,51,54] (Fig. 2). The assessment of bias for NRSs is shown in Table 2, where 2 studies were classified as moderate risk[2,24], 3 serious[1,17,35] and 2 critical.[21,23]

Meta-analysis

Perception of pain

Two meta-analyses were performed regarding the units of measurement and the follow-up periods used for the primary outcome, pain perception. The 1st meta-analysis included 83 patients in 4 studies that used micro-osteoperforation along with an evaluation scale of 1–10. The analysis showed a statistically significant increase in the pain score of patients with acceleration surgeries as compared with those who underwent conventional treatment within a 24-hour observation period. The mean increase on the pain analog scale was 0.46 (95% *CI*: 0.02, 0.91; $p = 0.04$), and the studies showed homogeneity: $\chi^2 = 0.17$; df = 3 ($p = 0.98$); $I^2 = 0\%$ (Fig. 3A). Four studies that used a scale of 1–100 were included in the 2nd meta-analysis, with a total of 136 patients who underwent corticotomy, piezocision and corticision. Acceleration surgeries and conventional orthodontics produced similar pain scores over a 7-day observation period. The non-significant difference was 12.41 (95% *CI*: −1.32, 26.13; $p = 0.08$), and the studies showed heterogeneity: $\tau^2 = 187.32$; $\chi^2 = 88.42$; df = 3 ($p < 0.00001$); $I^2 = 97\%$ (Fig. 3B).

Root resorption

Three meta-analyses were performed to assess root resorption as a secondary outcome. In the 1st overall assessment, we included 9 studies using corticotomy, piezocision, corticision, or micro-osteoperforation in 235 patients. There was a significant decrease in resorption in patients who received any acceleration surgery as compared to those who underwent conventional treatment.

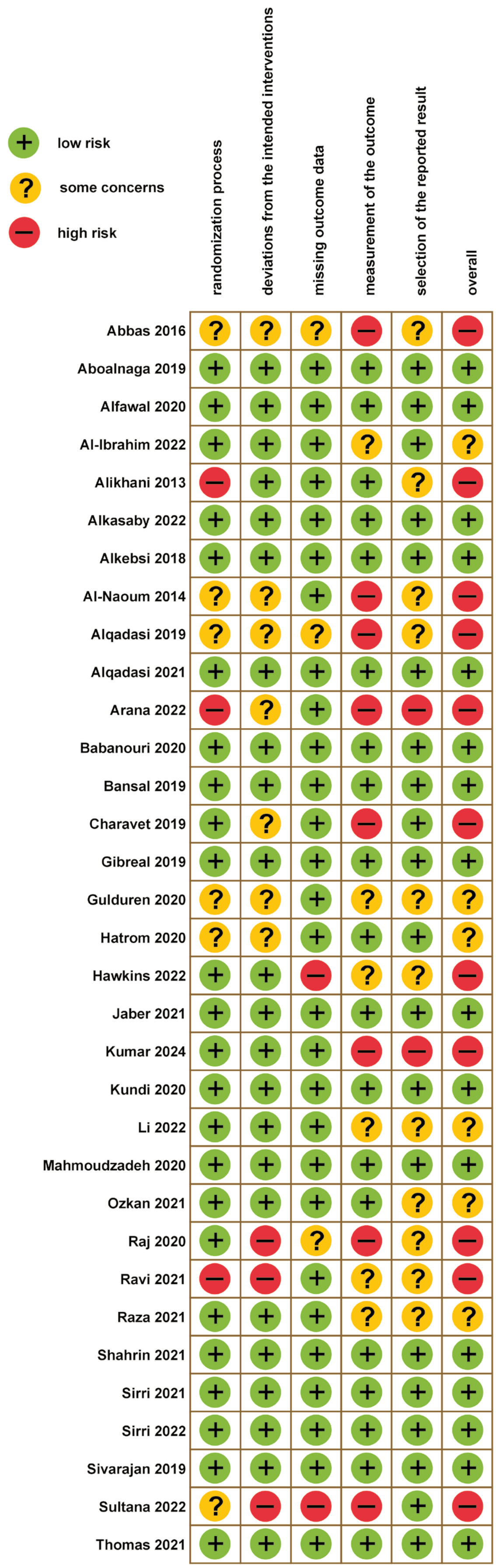


Fig. 2. Summary of the risk of bias (RoB) assessment for randomized controlled trials (RCTs) according to the RoB 2.0 tool

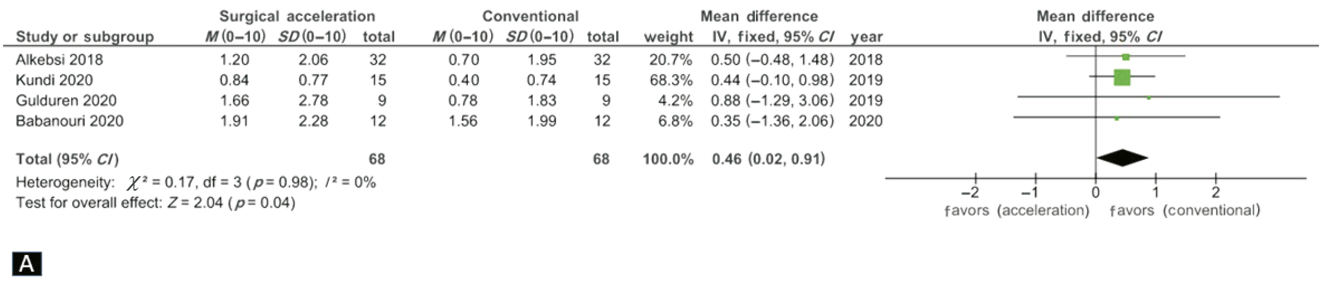
Table 2. Risk of bias (RoB) assessment for non-randomized studies (NRSs) according to the ROBINS-I tool

Study	Bias due to confounding	Bias in the selection of participants for the study	Bias in the classification of interventions	Bias due to deviations from the intended interventions	Bias due to missing data	Bias due to the measurement of the outcome	Bias due to the selection of the reported result	Overall risk of bias
Yavuz et al.[1] 2018	moderate	moderate	moderate	serious	no information	serious	serious	serious
Omidkhoda et al.[2] 2020	low	low	low	moderate	low	low	low	moderate
Shoreibah et al.[17] 2012	serious	moderate	serious	serious	no information	serious	moderate	serious
Patterson et al.[21] 2017	serious	low	serious	serious	low	critical	low	critical
Chan et al.[23] 2018	serious	low	serious	serious	low	critical	low	critical
Elkalza et al.[24] 2018	low	low	low	moderate	low	moderate	low	moderate
Ibrahim et al.[35] 2020	low	moderate	low	serious	no information	serious	low	serious

The mean decrease in root resorption was 0.24 mm (95% *CI*: −0.30, −0.17; $p < 0.00001$), and the studies showed homogeneity: $\chi^2 = 7.92$; df = 10 ($p = 0.64$); $I^2 = 0\%$ (Fig. 4A). Seven studies registered 155 patients and evaluated root resorption in retraction movements, showing a statistically significant decrease for patients who received corticotomy, piezocision or micro-osteoperforation as compared to conventional treatment. The mean decrease in root resorption was 0.26 mm (95% *CI*: −0.33, −0.18; $p < 0.00001$), and the included studies showed homogeneity: $\chi^2 = 5.68$; df = 8 ($p = 0.68$); $I^2 = 0\%$ (Fig. 4B). Finally, 2 studies evaluated root resorption in 80 patients during alignment movements. It was found that the patients who received corticision or micro-osteoperforation presented a significant decrease in root resorption of 0.16 mm as compared to conventional treatment (95% *CI*: −0.30, −0.01; $p = 0.03$), and the included studies showed homogeneity: $\chi^2 = 0.83$; df = 1 ($p = 0.36$); $I^2 = 0\%$ (Fig. 4C).

Discussion

The present systematic review summarizes the evidence from randomized and non-randomized clinical trials that compared surgical interventions to accelerate tooth movement vs. conventional treatment without acceleration with respect to adverse effects, such as pain perception and root resorption.



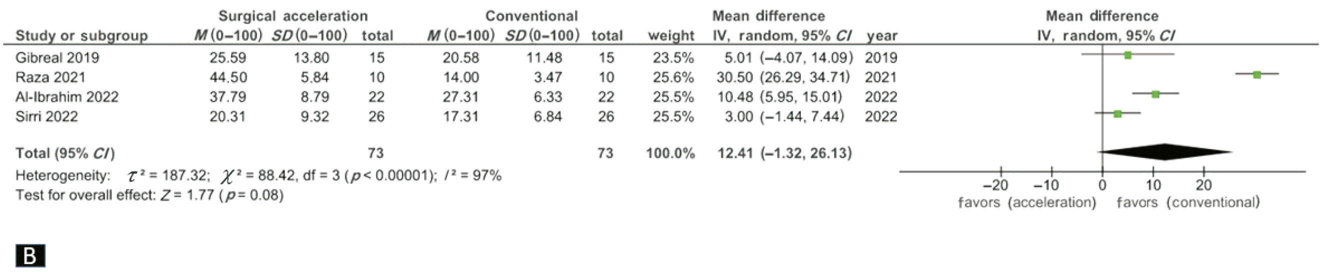


Fig. 3. Forest plot depicting the mean difference between surgical acceleration and conventional orthodontics for pain perception on assessment scales 1–10 (A) and on assessment scales 1–100 (B)

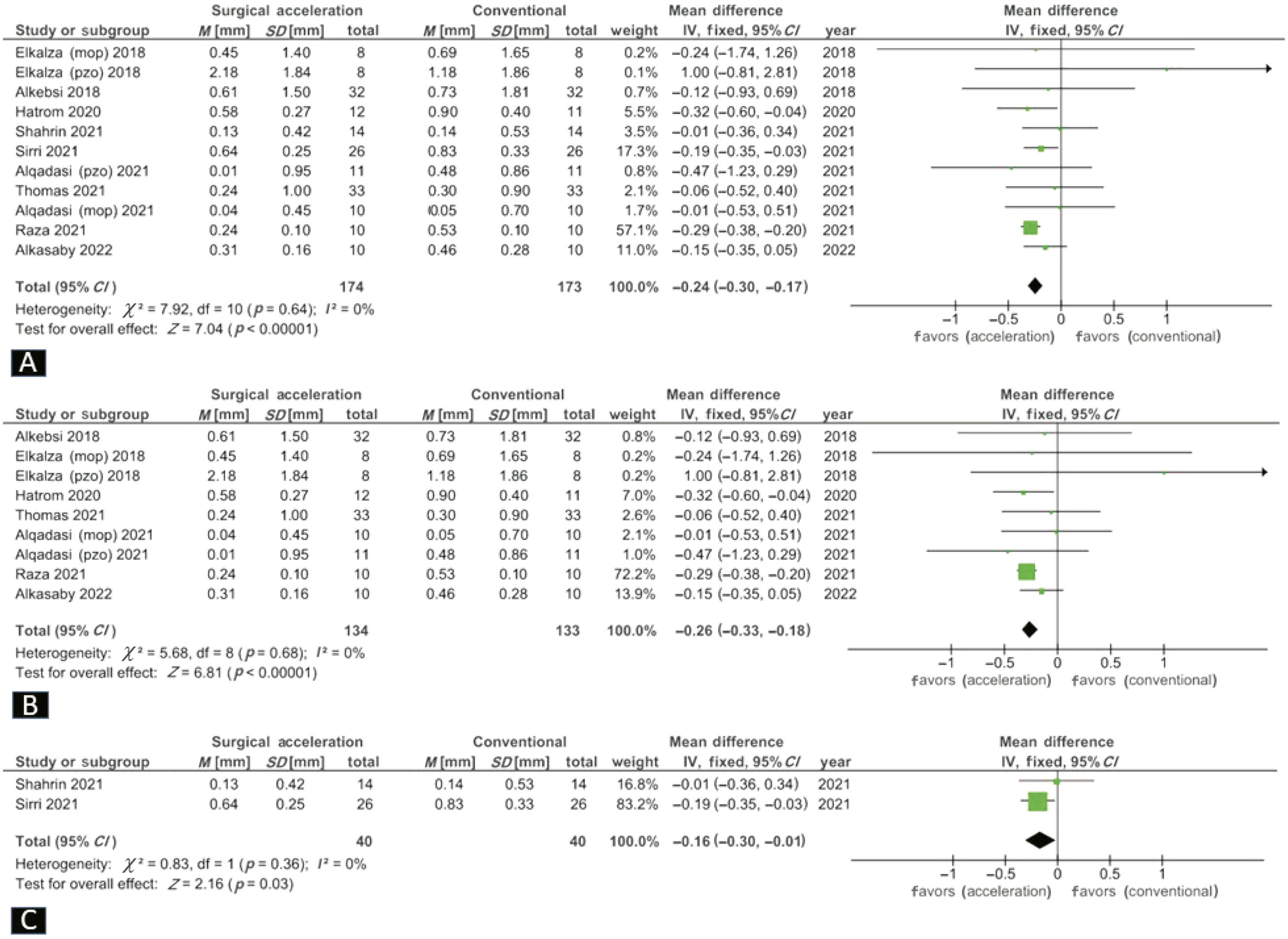


Fig. 4. Forest plot depicting the mean difference between surgical acceleration and conventional orthodontics for root resorption (A); in retraction (B) and in alignment (C)

The findings of this meta-analysis showed that surgical interventions together produced a greater perception of pain at 24 h, recorded on a scale of 0–10. The difference with regard to conventional treatment became nonsignificant when the analysis was performed at 7 days and on a scale of 0–100. Fu et al.[8] and MacDonald et al.[10] performed systematic reviews to assess pain perception in studies using acceleration surgery, but without quantitative analyses.

Dab et al.[9] and Mousa et al.[13] carried out meta-analyses to compare surgical interventions vs. conventional treatment with respect to pain perception without finding significant differences. However, some factors must be considered. Dab et al. included 2 studies that used periodontal accelerated osteogenic orthodontics (PAOO) and micro-osteoperforation, with the same units of measurement, but with unspecified follow-up time, and with the use of bone graft in one of the studies.[9] Mousa et al. analyzed 2 RCTs that also evaluated micro-osteoperforation with the same measurement scale and follow-up time, but only in canine retraction movements.[13] Although they found no differences, a similar trend was observed, which may become significant with a larger number of studies. In addition, it should be considered that the present study did not only include minimally invasive surgical interventions. The hyperalgesia described in the study can also be attributed to a cascade of inflammatory mediators, such as bradykinin, histamine, serotonin, and substance P, released by the action of prostaglandin E2 (PGE2) and the RANK/RANKL pathway as the first inflammatory messengers in osteoclastogenesis.[6,55] No differences were found between surgical interventions and conventional treatment in over a 7-day period, perhaps due to advancement toward a less invasive approach, where variations in the production of biochemical mediators associated with mild or moderate initial pain tend to decrease with postoperative time, even from the first day.[33] In addition, it is worth mentioning that pain recording was self-reported and might be subject to decreased sensory memory, which is observed at a longer evaluation period.[25]

With respect to the root resorption outcome, it was found that surgical interventions produced significantly less resorption in general. A different result was found by Dab et al., who performed a meta-analysis of 4 studies that reported their results in linear millimeters and cubic millimeters, with different follow-up times from one another.[9] The authors concluded that there was no significant difference in root resorption between patients who received any acceleration surgery and those who underwent conventional treatment.[9] However, the difference between both systematic reviews can be explained based on the criteria used in the present investigation, where only studies that reported the outcome in linear millimeters were considered. Although measurements made by cone beam computed tomography (CBCT) are more accurate, progress periapical radiographs are still the main method used to detect root resorption during treatment.[11] Furthermore, most of the studies that recorded measurements in cubic millimeters did not report complete quantitative data, or the follow-up period was insufficient. Consequently, a minimum acceptable follow-up of 3 months was established according to the literature.[7,11]

Acceleration surgeries caused less root resorption, which is partly due to the localized increase in the number of osteoclasts, which allowed a higher rate of movement with less root resorption.[5,6] However, there is evidence that the recruitment of factors like catabolic agents for remodeling can have an indiscriminate and deleterious effect on the surrounding tissues, e.g., cementum, ultimately depending on other factors, such as the application of optimal force.[12,32,56]

Finally, it is precisely the concept of the optimal application of force that can help explain the differences found between retraction and alignment movements. Although in both meta-analyses significantly less resorption was observed after acceleration surgeries as compared to conventional treatment, the difference was smaller in alignment movements, where the forces released may be less controlled with respect to retraction. In this sense, it should be considered that intrusion, retraction and torque movements by themselves may not be responsible for increasing the risk of resorption,[57] while the area of stress distribution, and the amount and lack of control of the force can play an important role in the exacerbation of root resorption in acceleration surgeries.[6,56]

Limitations

Among the main limitations are the deficiencies in reporting the results in the included studies, which precluded the inclusion of a greater number of investigations in the quantitative analysis. Although the number of participants was small in most investigations, this could have been offset by the number of investigations that were able to be included to maintain adequate power in the meta-analysis. It should be considered that only half of the trials included in the meta-analyses were assessed to have a low risk of bias with considerable heterogeneity, and this made it difficult to draw definitive conclusions. Future studies are needed, assessing not only the tooth movement rate, but also other patient-reported outcomes that could not be evaluated in the present systematic review, such as functional impairment (swelling, chewing, discomfort, mouth opening), the periodontal status and dental vitality.

Conclusions

Surgical interventions for the acceleration of tooth movement produced a greater perception of pain than conventional orthodontic treatment at 24 h of follow-up. However, the perception of pain was similar when it was evaluated after a period of 7 days.

Overall, there was evidence of significantly less root resorption in patients who received acceleration surgery for tooth movement in comparison with those who received conventional orthodontic treatment alone. Lower root resorption was also found when acceleration interventions were performed in tooth alignment movements, with a greater difference in retraction movements.

Ethics approval and consent to participate

Not applicable.

Data availability

All the data generated according to the objectives and methodology is published here. Any additional information can be obtained by contacting the corresponding author by e-mail.

Consent for publication

Not applicable.

ORCID iDs

Mariano Ortiz-Pizarro https://orcid.org/0000-0002-3472-9997
Marcos Jimmy Carruitero-Honores https://orcid.org/0000-0001-8339-5076
Silvio Augusto Bellini-Pereira https://orcid.org/0000-0002-7785-1634
Aron Aliaga-Del Castillo https://orcid.org/0000-0003-3963-1742

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