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Effect of Rapid Maxillary Expansion on Root Resorption: A Systematic Review of the Literature

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Abstract

Objective: Our work has as its main objective the evaluation of the occurrence of root resorptions through a systematic review of the literature. The secondary objective is to compare the classic RME and the MARPE, in order to guide our therapeutic choice towards an optimal risk-benefit ratio. ***Introduction***: Rapid maxillary expansion (RME) with multi-dental, bone or mixed support is today the therapy of choice in the treatment of maxillary endognathism. In order to maximize the orthopedic effects and minimize the iatrogenic dental effects, in particular the risk of external root resorption, a paradigm shift in anchoring has appeared and the use of bone anchoring techniques in the therapy of rapid maxillary disjunctions seems to increasingly appeal to practitioners. This systematic review analyzed the current literature to study the phenomenon of root resorption after RME based on 3D computed tomography and compare these iatrogenic dental effects according to the technique used between conventional tooth-supported expansion and mini-screw-assisted rapid palatal expansion (MARPE) ***Materials and Methods***: PubMed, Cochrane, Google Scholar and science direct were searched for systematic reviews, randomized or non-randomized controlled trials and cohort studies conducted in humans and published in the last 30 years (1994-2024). JBI was used for the risk of bias assessment of the included studies. ***Results***: A total of 11 articles: 3 systematic reviews, 6 retrospective cohort studies and 2 randomized controlled trial. ***Conclusion***: Our systematic review has proven the presence of root resorption and bone loss following rapid maxillary expansion with bone or tooth anchorage but we noted that the latter causes more significant damage to posterior teeth. In this regard, further studies testing different anchorage designs and using a consistent methodology for the assessment of root resorption are highly recommended.

Keywords: Rapid Maxillary Expansion, Root Resorption, 3D Imaging, MARPE.

Introduction

Maxillary expansion has been commonly used for over 150 years in Orthodontics. It is a therapy of choice for the treatment of maxillary endognathia in patients during the growth period [1].

According to Lagravère [19], rapid maxillary expansion (RME) has an orthopedic effect but also a dento-alveolar effect. The principle of this intermaxillary disjunction consists of generating heavy centripetal forces allowing the separation of the two maxilla at the median plane.

Isaacson *et al.*, showed that a single activation (¼ turn) produces forces transmitted to the maxilla ranging from 15 to 50 N. The multiplication of activations generates a cumulative effect of forces that can reach 100 N. Generally between the 9th and 12th activation, a diastema between the central incisors appears, thus marking the opening of the palatal suture [17].

During the active phase, significant forces are transmitted to the maxilla by the anchor teeth causing hyalinization of the periodontal ligament and blocking dental movements.

When activations stop, these forces decrease and the periodontal ligament reorganizes. When the residual forces reach the level of orthodontic forces, the induced dental movement can take place. It can be accompanied by iatrogenic effects on the alveolar bone and the roots of the posterior teeth, including the phenomena of root resorption (RR).

In order to avoid these iatrogenic effects and increase the ratio of skeletal effects to alveolar effects, a new perspective of anchoring expanders with microscrews appeared in clinical practice for the first time in 2010 [2]. This is the rapid palatal expansion assisted by miniscrews (MARPE).

The aim of MARPE is to increase mechanical efficiency and limit the iatrogenic effects including RR, which has long gone unnoticed due to silent clinical symptoms in the early stages of its development [6].

With the advent of 3D imaging, CBCT has changed the situation by revealing root and alveolar damage. The assessment of the amount of root resorption, linear or volumetric, has proven to be accurate and reliable [11-22].

We conducted a systematic review of the literature to study the phenomenon of RR after RME. One of our criteria being the presence of 3D imaging in order to compare the iatrogenic dental effects between dental-supported RME and MARPE.

MATERIALS AND METHODS

We conducted this systematic literature review according to the criteria published by the international PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analysis) recommendations.

1) Objective of the Study:

Our work has as its main objective the evaluation of the occurrence of root resorptions through a systematic review of the literature.

The secondary objective is to compare the classic RME and the MARPE, in order to guide our therapeutic choice towards an optimal risk-benefit ratio.

2) Eligibility Criteria:

The research elements were developed according to the PICOS (Population, Intervention, Comparison, Outcomes and Study design) scheme. All the articles included in this systematic review met the following criteria:

Table 1:

Domains	**Inclusion criteria**	**Exclusion criteria**
Population	Patients in the growth period with maxillary endognathism	-Animal. - Syndromic patients. - Patients with traumatized teeth.
Intervention	Treatment with a dental anchored expander.	- Orthodontic treatment with an appliance other than expanders. - Ortho-surgical treatment.
Comparison	Treatment with a bone anchored expander	No control group in the selected studies.
Results	- Amount of root resorption (in mm, mm3 or %). - Root length or volume at pre- and post-treatment. - CR/RR ratio.	Other results.
Type of study	- Systematic review (with or without meta-analysis). - Randomized and non-randomized controlled trial - Cohort study (retrospective or prospective). - Case-control study.	- Non-original article. - Narrative review. - Letter to the editor. - Case report. - Case series. - Expert opinion.
Other criteria	-Publication date from 1994. -English or French language. -Accessibility of the full text.	-Publication date from 1994. -English or French language. -Accessibility of the full text.

3) Search and Information Sources:

Two reviewers independently conducted a comprehensive search using a combination of controlled vocabulary (MeSH) and free text terms. PubMed, Cochrane, Google Scholar, and science direct were searched from January 1994 to December 2023. In addition to the publication date, search restrictions included only articles in English and French and the availability of full text and references. To answer the research question, it is necessary to search for all articles mentioning the rapid maxillary expander. Articles that studied the effects of root resorption caused by the use of a single type of expander were not considered. To do this, MeSH keywords were selected and combined with Boolean operators AND/OR/NOT to obtain the search equations used on the different electronic databases. The keywords used in the search were: “rapid maxillary expansion”, “adverse effects”, “root resorption”, “3D image”. Subsequently, a manual search was performed by browsing the reference lists of all included articles.

Table 2: Database search strategy

Database	Search strategy	
PubMed	RME, maxillary expansion, root resorption, external root resorption	maxillary expansion OR rapid maxillary expansion OR transverse maxillary expansion OR maxillary transverse deficiency AND root resorption NOT animals ((palatal expansion techniques [MeSH Terms]) OR maxillary expansion [Title/Abstract]) OR rapid maxillary expansion [Title/Abstract]) OR transverse maxillary expansion (Title/Abstract]) OR maxillary transverse deficiency [Title/Abstract]) OR SME[Title/Abstract]) OR RME[Title/Abstract]) OR RPE[Title/Abstract]) OR SPE[Title/Abstract])) AND (tooth resorption [MeSH Terms]) OR root resorption Title/Abstract]) OR apical root resorption [Title/Abstract]) OR external root resorption [title/Abstract]) OR EARR))) NOT ((animals [mh] not (humans [mh] and animals [mh])))
Cochrane	(maxillary expansion) OR (rapid maxillary expansion) OR (transverse maxillary expansion) OR (maxillary transverse deficiency) OR (SME) OR (RME) OR (RPE) OR (SPE)) AND ((root resorption) OR (apical root resorption) OR (external root resorption) OR (EARR))	"Root resorption" and rapid maxillary expansion
Google Scholar	RME, RAPID maxillary expansion, root resorption, external root resorption, CBCT not animals NOT SURGICAL not adults	
Science direct	Rapid maxillary expansion AND root resorption AND CBCT	

4) Study Selection:

The study selection process was conducted independently by two reviewers. All relevant articles were imported into Zotero, a bibliography generator. First, duplicate articles were eliminated. Subsequently, titles and abstracts were screened for eligibility. Then, articles that appeared to meet the inclusion criteria were read in full and analyzed. Finally, relevant articles were subjected to in-depth analysis. Disagreements regarding inclusion were resolved by discussion between the two reviewers.

5) Data Collection Process and Elements:

Data from the articles selected for this study were extracted using a predefined standardized form by two independent reviewers. Information collected included the author, year, number of participants, intervention, results, and author's conclusions. In case of doubt or disagreement between the two reviewers, resolution was achieved through discussion.

6) Risk of Bias:

Using the "JBI Critical Appraisal Tools" the members of the research group independently assessed the risk of bias in the included studies after the selection of the articles. After answering the questions listed in the checklists of the JBI Critical Appraisal Tool, the percentage of detailed information is calculated, which allows us to classify the risk of bias:

>70%, the study is considered to have a low risk of bias. Between 50 and 70%, the study has a moderate risk of bias.

<50%, the study has a high risk of bias.

The critical appraisal procedure and assessment scores are presented in Table 4 and 5.

7) Level of Evidence and Quality Assessment:

According to the "Oxford center of evidence-based medicine" [3], levels of evidence were assigned to the included articles.

RESULTS

1) Selection of Studies:

The writing of this systematic review of the literature was conducted according to the criteria published by the international PRISMA recommendations (Preferred Reporting Items for Systematic reviews and Meta-Analysis 2020). Initially, 1531 studies were identified in the database and in manual searches. Following the elimination of duplicates, 652 studies persisted, and only 11 passed the stage of the title and abstract screening. Finally, 9 articles were included in the final selection, as illustrated in the PRISMA flowchart (Figure 1).

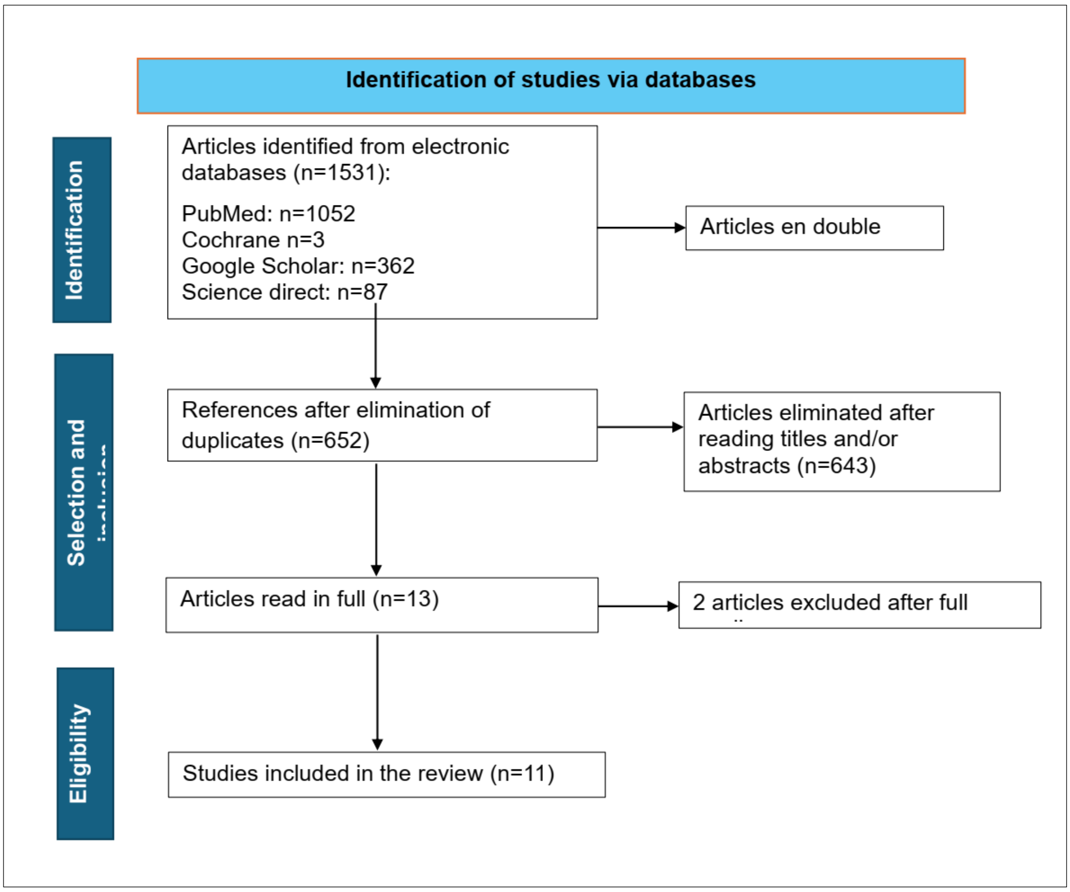

Fig. 1: Organization chart according to the PRISMA declaration

2) Characteristics of Included Studies:

11 relevant publications were identified as eligible according to the predefined inclusion criteria for this review: 3 articles were systematic reviews, 2 randomized controlled trials and the other 6 were retrospective cohort studies. The studies were collected with a publication date limited to 30 years, from 1994 to 2023.

3) Data Extraction and Synthesis:

The articles included in this systematic review and the data extracted from each study are presented in Tables 3 and 4.

Table 3: Overview of included studies on RR

Author	**Akyalcin, S**	**Jacob H.B**	**Baysal**	**Antonino Lo Giudice**	**Furkan Dindaroğlu**
Year	2015	2019	2012	2018	2015
Type of study	Retrospective cohort study	Randomized clinical trial	Retrospective cohort study	Systematic review	Retrospective cohort study
Number of participants	48 patients	19 patients	25 patients	3 articles	33 patients
Intervention	Conventional RME	Conventional RME	Conventional RME	Conventional RME	Conventional RME
Results	The author used CBCT scans and demonstrated a significant reduction in root volume and surface area for maxillary first premolars and molars after expansion compared with mandibular	Mesial roots showed an increase in length after RME (0.52 mm (p= 0.003)). Due to the age of the patients (7-10 years). It is known that the root of the maxillary first	-The difference between root volumes before and after RME was statistically significant for all roots studied. -The maximum volume loss was observed for the mesiovestibular	- Significant root volume loss was observed in the roots of all posterior teeth after RME - First molars are the most affected teeth (from 83.12 mm3 to 37.4 mm3), 1st and	-Root volume loss after conventional RME is significant for all posterior teeth - RR affects all posterior teeth similarly, whether they

	first premolars and molars used as controls ($P < 0.001$). In addition, the root length of maxillary first premolars and molars was reduced by 0.36 to 0.52 mm ($P < 0.05$).	molar is completed around the age of 10 years	root of the first molars (18.60 mm (3)), the distovestibular root of the first molars was less resorbed (9.47 mm (3)).	2nd premolars also show RR after RME	are anchorage-supporting (M1 and P1) or not (P2) - Root volume variations after 6 months of consolidation were not statistically significant for all teeth studied.
Conclusion	RME causes a statistically significant decrease in root height and volume of posterior teeth	RME does not interrupt root formation and does not show RR of the first molar in juvenile patients. (7 to 10 years)	CBCT imaging showed statistically significant volume loss in all posterior teeth roots (premolars and first molar) after RME. No statistically significant differences were found for the percentage of root volume loss.	-RME causes volume loss in the roots of posterior teeth. However, when expressed as a percentage, root volume loss was similar between anchored teeth (first molars and first premolars) and non-anchored teeth (second premolars).	The heavy forces generated during RME affect all posterior teeth in a similar manner, whether or not they are anchored Root repair was observed for all posterior teeth after 6 months of consolidation

Table 4: Overview of included studies comparing RME and MARPE

Author	Marietta Krüsi	Sarah Abu Arqub	Celenk-Koca	Mucahid Yildirim	Shivam Mehta	Rosalia Leonardi
Year	2019	2022	2018	2019	2022	2023
Type of study	Systematic review	Systematic review	Randomized clinical trial	Retrospective cohort study	Retrospective cohort study	Retrospective cohort study
Number of participants	12 articles	13 prospective studies: - 6 randomized clinical trials - 7 non-randomized clinical trials	40 patients	20 patients	60 patients	40 patients
Intervention	Rapid maxillary disjunction with dental and bone anchoring	Rapid maxillary disjunction with dental and bone anchoring	Rapid maxillary disjunction with dental and bone anchoring	Rapid maxillary disjunction with dental and bone anchoring	Rapid maxillary disjunction with dental and bone anchoring	Rapid maxillary disjunction with dental and bone anchoring
Results	Little or no difference in root resorption volume at 1st molar level after consolidation period	- Studies using 3D microtomography imaging have shown that MARPE would result in less RR than conventional RME devices. RR occurs more frequently on the vestibular surfaces of maxillary posterior teeth (first	-No significant differences were observed in root length changes between tooth-supported RME and MARPE groups	The RR affecting the cervical, median and apical third of the root is more significant with dental anchorage compared to bone anchorage ($P<0.05$). The two median and apical thirds are more affected by	No significant difference in root resorption between RME and MARPE	Comparative analysis of CBCTs taken at T0 (before treatment) and T1 (3 months after treatment) showed: - A significant reduction in the volume and length of all posterior teeth

		molar most affected) - However, a study using CBCT did not show any difference in root resorption with MARPE and conventional RME models		resorption compared to the cervical third.		studied ($p<0.05$) in the 2 groups, RME with dental support and MARPE - The first molar M1 presents a significant decrease in volume than the 2 premolars P1 and P2. - No significant difference between the teeth studied in each group when the volumetric loss is expressed as a percentage of the total root volume. - The volumetric loss is remarkably greater for each tooth studied in the tooth-supported RME group, The percentage of volumetric loss also ($p<0.05$) - The decrease in the length of the palatal root of M1 is the most important ($p<0.05$). - For each tooth studied, The reduction in root length was significantly greater in the tooth-supported RME group compared to the MARPE group ($p<0.05$).
Conclusion	The results offered by bone anchoring are better but this hypothesis cannot be confirmed due to the limited number of research studies.	RME may cause root resorption of maxillary posterior teeth MARPE may cause less root resorption than RME.	No significant adverse effects after maxillary expansion	RME caused more resorption in the vestibular than in the palatal. No significant resorption with MARPE	No significant difference in root resorption between the two groups	- 3 months post activation, the observed RR (root volume and length) is significantly greater in the tooth-supported RME group ($p<0.05$) - The root volume of M1 and the length of its palatal root are the most

						affected by RR during RME - The 3D root models show that the RR is located mainly at the level of the meso-vestibular roots. - Although they are not anchorage supports, the 1st premolars were affected by RR during RME in both techniques. The transmission of forces is not limited to the anchorage teeth

4) Risk of Bias of Included Studies:

4-1) Systematic Reviews

Table 5: Risk of bias of systematic reviews according to JBI

Article	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Note
1	Y	Y	Y	Y	Y	Y	N	N	NC	Y	N	63% Moderate risk of bias
2	Y	Y	Y	Y	Y	Y	N	NC	NC	Y	Y	72% Moderate risk of bias
3	Y	Y	Y	Y	Y	Y	NC	N	NC	Y	N	63% Moderate risk of bias

Y:Yes, N: No, NT: Not clear.

4-2) Cohort Studies:

Table 6: Risk of bias of cohort study reviews according to JBI

Article	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Note
1	Y	Y	Y	Y	Y	Y	Y	Y	NC	N	N	Y	75% Low bias risk
2	Y	Y	Y	Y	Y	Y	N	NC	N	Y	N	Y	66% Moderate risk of bias
3	Y	Y	Y	Y	NC	Y	Y	NC	NC	N	NC	Y	44% High bias risk
4	Y	Y	Y	Y	Y	Y	N	NC	NC	N	NC	Y	58% Moderate risk of bias
5	Y	Y	Y	Y	Y	Y	NC	NC	NC	N	NC	Y	58% Moderate risk of bias
6	Y	Y	Y	Y	Y	Y	Y	NC	N	Y	N	NC	66% Moderate risk of bias

Y:Yes, N: No, NT: Not clear.

4-3) Randomized Clinical Trial

Table 7: Risk of bias of randomized clinical trials of cohort studies according to JBI

Article	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Note
1	Y	Y	NC	Y	Y	NC	NC	N	NC	N	Y	NC	NC	41% High bias risk
2	Y	Y	Y	Y	Y	NC	Y	Y	N	NC	Y	Y	NC	66% Moderate risk of bias

Y:Yes, N: No, NT: Not clear.

5) Level of Evidence of Included Studies:

Table 8: Level of scientific evidence of the included studies

References	Level of evidence	Grade of recommendation
1	2b	B
2	1b	A
3	2b	B
4	1b	A

References	Level of evidence	Grade of recommendation
5	2b	B
6	1b	A
7	1a	A
8	2b	B
9	2b	B

The level of scientific evidence is assigned to each of the included studies according to the criteria described by the Oxford Centre for Evidence-based Medicine and presented in Table 6.

DISCUSSION

RR is a pathological phenomenon that is defined as a permanent lesion that can extend from a fraction of a millimeter to more than half of the root and thus seriously compromise the stability of the tooth [30-32].

Histological studies were the first to demonstrate root resorption on anchor teeth following RME [1-12]. These are invasive methods requiring extraction of the premolars after RME in order to observe the roots via optical microscopy or scanning electron microscopy.

Conventional radiographs (retroalveolar radiography, orthopantomogram, lateral teleradiography) have also been used. Chan *et al*., consider these radiographs inadequate for detecting and assessing all but the most advanced resorptive lesions and should be avoided [18].

With the advent of 3D imaging (late 1990s), cone beam assessment of the amount of root resorption, whether linear or volumetric, has proven to be accurate and reliable [9, 7].

Baysal *et al*., reportedly conducted the first study in the literature in which 3D measurements were performed to assess the amount of apical resorption in posterior teeth following RME.

This study involved 25 children aged 11 to 14 years with immature root development.

Three-dimensional images of the first permanent molars and first and second premolars showed that the difference in root volume before and after RME was statistically significant for all roots studied. The maximum loss was observed in the mesio-buccal roots of molars [14-25].

In a study published in 2015, Akyalcin, S [15], demonstrated, through a comparative analysis of CBCT, that RME causes a significant decrease in the root volume of posterior teeth (12.4 mm3).

These results have been confirmed by other studies. Baysal. A [14], and Dindaroğlu [10], also used 3D imaging and evaluated the root volume before and after RME, a statistically significant volume difference was found in all roots of posterior teeth, 18.6mm3 and 40.86 mm3, respectively. However, it is not possible to make a comparison between these 3 studies due to the heterogeneity of the methods applied.

The results of the studies in our review also established that:

- The first molars are the most affected teeth.
- The maximum volume loss was observed for the mesiovestibular root of the first molars, the distovestibular root of the first molars was less resorbed. This volume loss also affects the first and second premolars [34].
- When expressed as a percentage, the root volumetric loss was similar for all posterior teeth, whether they were anchorage supports (first premolar and first molar) or not (2nd premolar). However, these data are contradictory with those of another study which did not observe any resorption at the level of the non-banded premolars, suggesting that these teeth moved laterally with the alveolar process [31].
- The length of the roots of the maxillary first premolars and molars was reduced after RME [13]. Contradictory results were reported by Jacob.H.B [1], in 2019. According to this study, the length of the mesial roots increased after RME treatment (0.52 mm ($p = 0.003$)). The patients in the group were aged 7-10 years, the root apices continued after the intermaxillary disjunction, which could explain this increase in the length of the roots of the teeth studied. He concluded that RME does not alter the formation of molar roots in the youngest patients.

It appears that root resorptions are among the iatrogenic effects frequently encountered during our RME treatments. They would be due to the significant forces transmitted to the maxilla. Barber and Sims questioned the need for such high forces for maxillary expansion and assumed that such forces would resorb the roots of the anchor teeth [24]. Skeletal anchorage has been proposed to reduce the forces and decrease the risk of RR.

Despite the ease of use and accuracy of 3D radiographic techniques, there are few studies with comparative data on RR between dental and skeletal anchorage-assisted RME. Our literature review included and examined 11 articles.

The results showed that there is little or no difference in the volume of root resorption at the 1st molar level. The measurements were made after the consolidation period [4-29].

In a literature review, Sarah Abu Arqub [22], reported that studies using 3D microcomputed tomography imaging showed that MARPE would result in less RR than conventional RME devices. However, the study that used CBCT claims that the difference between the 2 techniques is not significant. RR would occur more frequently on the vestibular surfaces of the maxillary posterior teeth. The first molar is the most affected.

In the studies of Celenk-Koca [13], and Shivam Mehta [19], the results of CBCT did not find a significant difference in root volume or length loss between the tooth-supported RME and MARPE groups.

The comparative analysis in the studies of Rosalia Leonardi [16], and Mucahid yildirim [6], revealed a significant reduction in the volume and length of all the posterior teeth studied ($p < 0.05$) in the 2 groups: tooth-supported RME and MARPE.

The volumetric loss and the decrease in the length of the roots of the teeth studied are significantly higher for each tooth studied in the tooth-supported RME group.

A more significant RR is found at the level of the mesio-vestibular roots in both groups. The 2nd premolars present a RR similar to that found at the level of the anchorage support teeth (1st premolar and 1st molar)

In the study of Weltman B, it appears that the RR process after RME continues during the consolidation period because of residual forces [28].

However, the impact of RR on the viability and function of the affected teeth has not yet been elucidated [19]. Our review showed that RME causes RR in maxillary first molars and first and second premolars. A preliminary assessment of patient-related risk factors is therefore strongly recommended before RME in patients with increased risk of RR [5].

In an interview on external apical resorptions in orthodontics, W. BACON and P. CANAL recommend, in case of doubt of systemic deregulation identified or suspected in the anamnesis, to perform a biological assessment testing parathyroid hormone (PTH), calcium (Ca), phosphorus (P), vitamin D (Vit D) and possibly thyroid-stimulating hormone (TSH).

Although the current results suggest that bone-anchored rapid maxillary expansion induces less root resorption compared to dental anchorage, the magnitude of the differences could be considered statistically insignificant. Therefore, the use of miniscrews as skeletal anchorage in RME cases should take into account other specific factors such as patient age, skeletal maturity, and dentoalveolar compensation of transverse insufficiency [8-23].

Limitations:

This systematic review has several limitations:

- The number of articles
- Our selection of articles was limited to articles available online and freely accessible, as well as those published or translated in English or French. This approach would likely have excluded relevant scientific studies published in other languages, thus posing a selection bias.
- We conducted our search over the last 30 years of publication and we chose to limit the included studies to those that used three-dimensional imaging as a means of exploring RR. However, CBCT was first used in the early 2000s. Furthermore, the first study in the literature in which 3D measurements were performed to assess the amount of apical resorption on posterior teeth after EMR was published in 2012 [11]. It would have been more appropriate to limit our search to the last 20 years
- Our systematic review showed that most studies had a moderate level of evidence. Therefore, a cautious interpretation of the results is necessary.
- The studies did not specify whether these iatrogenic effects at the root level compromised the durability of teeth on the arches, at least in the short term.

CONCLUSION

Although the risk of RR is a real concern for the orthodontist, there is currently, due to a lack of sufficient comparative studies, no consensus as to the superiority of one of the different devices.

If not inevitable, this risk must then be controlled and minimized.

This systematic study analyzed the current literature and demonstrated, using a 3D radiographic evaluation, that RME causes RR in the posterior teeth.

RR is present in all orthopedic maxillary expansion techniques, conventional or Marpe.

However, studies have shown that this iatrogenic effect is more significant in conventional techniques.

There is therefore little chance of escaping the risk of RR after RME.

In this regard, further studies testing different anchorage designs and using a consistent methodology for the assessment of root resorption are highly recommended

Conflict of Interest: The author declares that he has no conflict of interest concerning the data published in this article.

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