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ORIGINAL RESEARCH

Pain and Tissue Damage in Response to Orthodontic Tooth Movement: Are They Correlated?

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ABSTRACT

Aim: To evaluate the correlation between pain and tissue damage in response to orthodontic tooth movement (OTM), such as hyalinization and external apical root resorption (EARR).

Materials and methods: The literature review was used as a methodological strategy, following the knowledge development process – constructivist (ProKnow-C). Study axes were defined and keywords that best represented each axis were selected. The terms were submitted to an adherence test and validation, resulting in 12 keyword combinations. Searches were carried out in the most representative databases for the selected terms, without restriction as for language or publication dates. Retrieved studies were filtered using the EndNote X6 program and classified according to analysis of title, abstract, and keywords. The final portfolio of articles was submitted to bibliometric and systematic analysis.

Results: A total of 1,091 studies were retrieved, out of which 719 were repeated and 335 were removed in the classification stage. A total of 37 articles remained in the final portfolio. Only one article was in line with the purpose of this study, indicating absence of correlation between pain and EARR in response to OTM.

Conclusion: Further studies are necessary to confirm whether orthodontic pain might serve as a criterion for the use of appropriate mechanical forces, contributing to minimize tissue damage following OTM.

Clinical significance: This article presents a systematic literature review, in which scientific evidence of the correlation between pain and tissue damage during orthodontic movement was studied, providing a scientific answer for the following question: Is pain reported by patients associated with application of inappropriate orthodontic force? Thus, it aims at aiding the orthodontist in the definition of clinical parameters for the use of optimal orthodontic force.

Keywords: Hyalinization, Pain, Root resorption.

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INTRODUCTION

Orthodontic tooth movement (OTM) is a result of the application of mechanical forces to the teeth. Orthodontic forces represent mechanical stimuli that trigger a series of tissue reactions in the periodontal ligament and alveolar bone. These reactions result in alveolar remodeling by resorption and bone apposition processes, allowing tooth displacement.[1] However, this process is often followed by unwanted tissue damage, mainly the formation of hyalinization areas in the periodontal ligament and the incidence of external apical root resorption (EARR).[2] Such unwanted tissue damage is related to the application of a biologically inappropriate force system, due to intensity, duration, or distribution.[1,3-5]

The use of biologically compatible mechanical forces is a great challenge to orthodontic treatment. Besides the subjectivity inherent in the concept of ideal mechanical

force and individual variability, the absence of tools that allow measuring the intensity of force applied to different root regions should be emphasized.[1,6]

One of the clinical observations that can be made during orthodontic treatment is the patient report on the perception of pain. Pain associated with OTM results from mechanical stimulus and from the inflammatory reaction to tensile and compressive stress in the periodontal ligament.[7] It is questioned, however, whether pain in response to OTM is associated with the application of inappropriate mechanical forces and, consequently, to the incidence of unwanted tissue damage. Thus, the aim of this study was to evaluate the correlation between pain and tissue damage in response to OTM, such as hyalinization and EARR, through literature database analysis. The results may allow the use of patient self-reported pain as clinical criterion to collaborate in the determination of appropriate orthodontic mechanical force, avoiding the incidence of tissue damage associated with orthodontic treatment.

MATERIALS AND METHODS

The methodological procedures used in this study followed the knowledge development process – constructivist (ProKnow-C).[8] The study was carried out in February and March 2015, according to the stages illustrated in Figure 1.

Firstly, three study axes were defined: OTM (group I), orthodontic pain (group II), and unwanted tissue damage in response to OTM (group III). After the detailed study of these themes, keywords to be included in each group were defined. Three keyword categories were included in group I, two in group II, and two in group III. Following the definition of keywords, possible synonyms and derivations were also considered. The terms were submitted to an adherence test, which consists of the evaluation of the feedback each keyword produced when searched in databases. The adherence test allowed checking the importance of each keyword, deleting those without much representativeness. The literature databases used for the adherence test were Google scholar and CAPES portal of journals. The latter is the Brazilian national electronic library consortium for science and technology. The keywords included in each category of each group, with their synonyms and derivations, as well as adherence test results for groups I, II, and III are shown in Tables 1 to 3 respectively.

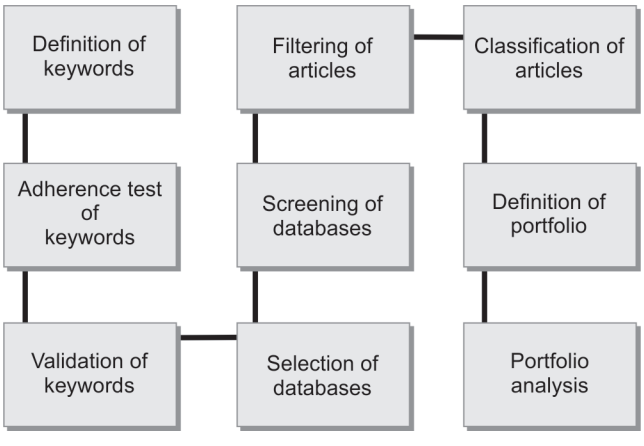

Fig. 1: Methodological stages

Table 1: Adherence test group I

Category	Keyword	CAPES journals	R%*	Google Scholar	R%*
	"orthodontic movement"	0.515	0.20	5.000	0.70
1	"orthodontic treatment"	36.513	16.80	97.700	14.00
	Orthodontics	52.534	24.30	210.000	32.90
	orthodontic*	101.639	46.70	289.000	46.50
2	"tooth movement"	6.203	2.90	32.500	5.00
	"teeth movement"	14.550	5.00	1.190	0.20
3	"tooth displacement"	4.533	2.20	3.250	0.50
	"displacement of teeth"	4.268	1.90	1.410	0.20
	Total	209.094	100.00	666.450	100.00

*Percentage representativeness

Table 2: Adherence test group II

Category	Keyword	CAPES Journals	R%*	Google scholar	R%*
1	*"pain"*	888.281	94.60	3.050.000	78.30
2	*discomfort*	50.317	5.40	0.848.000	21.70
	Total	938.598	100.00	3.898.000	100.00

*Percentage representativeness

Table 3: Adherence test group III

Category	Keyword	CAPES journals	R%*	Google scholar	R%*
1	hyalinization	1.319	1.08	24.500	29.26
	"hyalinized areas"	0.33	0.03	0.609	0.73
	"hyalinized area"	0.14	0.01	0.216	0.26
	"hyalinized zones"	0.4	0	0.239	0.29
	"hyalinized zone"	0.12	0.01	0.280	0.33
	"hyalinized tissue"	0.51	0.04	0.743	0.89
	"hyaline areas"	0.145	0.12	1.190	1.42
	"hyaline area"	0.133	0.11	1.740	2.08
	"hyaline zones"	0.169	0.14	0.810	0.97
	"hyaline zone"	0.351	0.29	1.520	1.82
	"hyaline tissue"	0.304	0.25	1.360	1.62
	hyalin*	97.029	79.40	25.700	30.69
2	"root resorption"	22.254	18.21	23.900	28.54
	"apical resorption"	0.383	0.31	0.927	1.11
	Total	122.201	100.0	83.734	100.0

*Percentage representativeness

Following analysis of the adherence test in group I, all terms from category 1 were replaced by the term *orthodontic*, followed by (*). This truncation tool allows the retrieval of the word root, as well as its variations by different suffixes. Thus, by using a simple study method, all category 1 terms in group I would be retrieved. The terms "tooth displacement" and "displacement of teeth" were removed due to low representativeness.

Terms widely used in the orthodontic literature were included in group II to refer to pain in response to OTM. These terms are broad enough and produced a significant number of feedbacks in the databases. In addition, the literature is quite specific as for their use, and the use of derivations or synonyms was not found in the studied context. Therefore, it was not considered necessary to include other terms to represent them.

In group III, category 1, the term hyalin followed by (*) was selected in substitution of all other derivations. In category 2, the term "apical resorption" was removed due to low representativeness.

After the adherence test, keywords were submitted to validation by an experienced investigator in the area. Table 4 shows the final set of keywords selected for each group. As a result, 12 combinations were created to be searched in databases (permutation: Pn = $n!$ or $3 \times 2 \times 2 = 12$).

The next stage consisted of the selection of databases from tests carried out in the CAPES portal of journals. Boolean searches were performed with keywords and the databases that produced the highest number of retrievals were selected: Scopus, Medline via PubMed, and Web of Science. Following the study of the functioning of the selected bases, the screening process for the 12 keyword combinations was performed. There was no restriction as for language or publication date. The retrieved studies were exported using EndNote X6 program.

Subsequently, studies were filtered using the EndNote X6 tools, aiming at identifying and removing duplicate ones. The following stage consisted of the classification of articles, through analysis of title, abstract, and keywords. As classification criterion, all studies that evaluated pain, hyalinization, and/or EARR in response to OTM were selected. Thus, the final portfolio of articles was defined, which was subjected to bibliometric and systematic analysis. The bibliometric analysis aimed at identifying the following elements: Author, country of origin, year of publication, journal, and sampling details. In the systematic analysis, besides identifying the evaluated aspects of interest (pain, hyalinization, and/or EARR), it was verified whether the purposes of the articles were in line with the purpose of this present study.

Table 4: Selected keywords

	Group I		*Group II*		*Group III*	*Combinations*
	orthodontic*		"pain"		hyalin*	
	"tooth movement"		discomfort		"root resorption"	
	"teeth movement"					
Total	3	×	2	×	2	12

RESULTS

Flow Chart 1 illustrates the results of the filtering and classification stage. A total of 1,091 studies were retrieved, out of which 719 were duplicate and therefore excluded. Subsequently, 372 studies were selected. As a result of the classification stage, 306 articles were excluded. Moreover, in this stage, it was identified that 25 studies were books and 4 were patents; consequently, they were also discarded. The final portfolio consisted of 37 articles,[9-45] which were submitted to bibliometric and systematic analysis.

The results of the bibliometric and systematic analyses can be visualized in Table 5. The selected studies were published between 1996 and 2014, 59.46% being published in 2009. Countries with the highest number of publications were Japan (35.14%, individually or in collaboration with other countries), Brazil (13.51%), Germany (10.81%), and the United States (10.81%). Journals that mostly addressed the analyzed keywords were American Journal of Orthodontics and Dentofacial Orthopedics (21.62%), European Journal of Orthodontics (18.91%), and The Angle Orthodontist (13.51%). As for the sampling, 64.86% of studies were performed with patients and 27.03% used rats. In two studies, the interventions were carried out in beagles and in patients (5.41%) and in one study, questionnaires were applied to orthodontists (2.70%).

Regarding the investigated aspects of interest, 59.46% of studies evaluated EARR, 18.92% EARR and pain, 16.22% pain, 2.70% hyalinization, and 2.70% hyalinization and EARR. None of the selected studies aimed at evaluating the correlation between pain and unwanted tissue damage in response to OTM. However, one article[39]

Flow Chart 1: Filtering and classification of articles

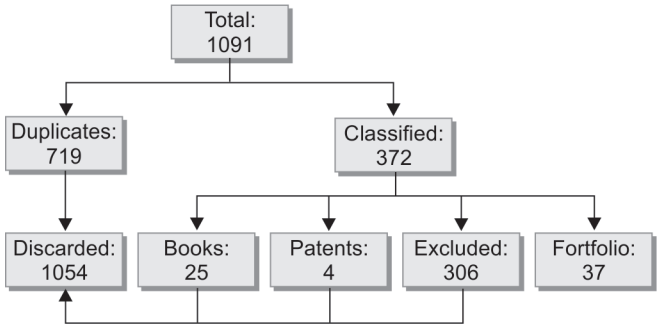

Table 5: Results of bibliometric and systematic analysis

Evaluated aspects of interest	*Author(s)*	*Years*	*Country of origin*	*Journal*	*Sample*	*Study purpose in line with purpose of present study*	*Results/conclusions related to purpose of present study*
Hyalinization	Tomizuka et al	2007	Japan	Angle Orthod	Rats	No	None
	Deguchi et al	2008	Japan	Am J Orthod Dentofacial Orthop	Patients	No	None
	Diedrich et al.	1996	Germany	Am J Orthod Dentofacial Orthop	Patients	No	None
	Fonseca et al	2013	Brazil	Lasers Med Sci	Rats	No	None
	Gameiro et al	2008	Brazil	Orthod Craniofac Res	Rats	No	None
	Gulden et al	2008	Germany	J Orofac Orthop	Patients	No	None
	Handelman	1997	United States	Angle Orthod	Patients	No	None
	He et al	2014	China	J Dent Res	Rats	No	None
	Jacobs et al	2014	Germany	Head Face Med	Patients	No	None
	Karadeniz et al	2011	Australia, Turkey	Am J Orthod Dentofacial Orthop	Patients	No	None
	Kau	2011	United States	Head Face Med	Patients	No	None
EARR	Kumar et al	2013	India	J Int Oral Health	Patients	No	None
	Kuroda et al	2013	Japan and Canada	Clin Oral Investig	Rats	No	None
	Liu et al	2004	Japan	Eur J Orthod	Rats	No	None
	Marquezan et al	2013	Brazil	Dental Press J Orthod	Rats	No	None
	Nimeri et al	2014	United States	Clin Cosmet Investig Dent	Patients	No	None
	Sakai et al	2008	Japan	Angle Orthod	Patients	No	None
	Scott et al	2008	United Kingdom	Am J Orthod Dentofacial Orthop	Patients	No	None
	Sirisoontorn et al	2012	Japan, Thailand, Australia	Am J Orthod Dentofacial Orthop	Rats	No	None
	Souza et al	2011	Brazil	Photomed Laser Surg	Patients	No	None
	Vandevska-Radunovic; Murison	2010	Norway	Eur J Orthod	Rats	No	None
	Winter et al	2009	Norway	Eur J Orthod	Patients	No	None
	Yamada et al	2009	Japan	Angle Orthod	Patients	No	None
	Alikhani et al	2013	United States	Am J Orthod Dentofacial Orthop	Patients	No	None
	Arantes et al	2009	Brazil	Orthod Craniofac Res	Patients	No	None
Pain	Doshi-Mehtaa; Bhad-Patil	2012	India	Am J Orthod Dentofacial Orthop	Patients	No	None
	Insee et al	2014	Thailand	Eur J Orthod	Patients	No	None
	Ogura et al	2009	Japan and China	Eur J Orthod	Patients	No	None
	Sudhakar et al	2014	India	J Pharm Bioallied Sci	Patients	No	None
Hyalinization, EARR	Kogure; Noda	2009	Japan	Orthod Waves	Rats	No	None

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Evaluated aspects of interest	*Author(s)*	*Years*	*Country of origin*	*Journal*	*Sample*	*Study purpose in line with purpose of present study*	*Results/conclusions related to purpose of present study*
	Cakmak et al	2014	Turkey and Australia	Am J Orthod Dentofacial Orthop	Patients	No	Yes: authors observed correlation between pain and EARR
	Mandall et al	2006	United Kingdom	Eur J Orthod	Patients	No	Indirectly: authors observed no differences concerning EARR and pain in the different evaluated interventions
	Moon et al	2007	South Korea	Angle Orthod	Patients	No	Indirectly: authors observed no EARR or pain associated with the evaluated intervention
EARR, pain	Noda et al	2006	Japan	Orthod Waves	Beagles; patients	No	Indirectly: authors observed no EARR or pain associated with the evaluated intervention
	Noda et al	2007	Japan	Eur J Orthod	Beagles; patients	No	Indirectly: authors observed no EARR or pain associated with the evaluated intervention
	Schuster et al	2005	Germany	J Orofac Orthop	Orthodontists	No	None
	Villa et al	2005	Colombia	J Endod	Patients	No	Indirectly: evaluated intervention reduced EARR and pain

presented, among its results, absence of correlation between pain and EARR in response to OTM. In addition, five studies[40-43,45] presented results that can be indirectly related to the purpose of the present study. These studies suggested that there is a correlation between pain and EARR in response to OTM.

DISCUSSION

The present study aimed at evaluating the correlation between pain and unwanted tissue damage in response to OTM. The methodological strategy used was a review of the literature, guided by the knowledge development process – constructivist (ProKnow-C). This process is characterized by a thorough database search method. It involves the definition of study axes, a detailed selection of keywords, as well as databases in which the searches will be carried out. Keyword crossing guarantees the specificity of the search for the study purpose.[8]

Once the bibliographical portfolio is defined, after the filtering and classification stages, the ProKnow-C recommends the bibliometric analysis of the selected studies, which allows learning about the bibliographical elements that are mostly significant in the area of knowledge, such as authors, year of publication, journals, and country of origin. Finally, the systematic analysis allows understanding the state of the art in the investigated subject, as well as identifying points that need to be improved or that have not been explored yet. Thus, it allows identifying aspects that deserve to be investigated in order to expand the frontier of knowledge in a determined subject. As a consequence, one of the applications of the ProKnow-C process is the proof of unprecedented or nonsimilar studies.[8]

Three study axes were defined in the present study: OTM, pain, and unwanted tissue damage in response to OTM. The bibliometric analysis of the bibliographical portfolio revealed an increase of scientific manuscripts related to the subject over the last years. It also demonstrated that most retrieved studies were published in three high-impact journals in the orthodontics area, evidencing the scientific quality of the bibliographical portfolio. It also allowed identifying countries with major scientific production related to the specific study purpose, particularly Japan. In addition, important methodological aspects of the selected studies were revealed, such as type of adopted sampling and other investigated aspects of interest.

The systematic analysis revealed that the study developed by Cakmak et al[39] showed results in line with the purposes of the present study. The authors aimed at evaluating the quantity of EARR in premolars submitted to occlusal trauma due to addition of restoring material to the occlusal surface during 4 weeks. Additionally,

during the first 7 days of the experimental period, the patients were instructed to register the level of pain produced by the procedure in an analogous visual scale. The authors did not observe a correlation between quantity of EARR and pain. Other studies presented results that can be indirectly related to the purposes of the present study.[40-43] These studies observed that the performed interventions promoted OTM without producing EARR or pain. Villa et al[45] reported that the use of medication was efficient in reducing the quantity of EARR and pain after OTM. These studies suggested that there is a correlation between EARR and pain resulting from OTM, since these variables behaved similarly in response to the different interventions.

According to the methodology employed in the present study, the best evidence available in the literature[39] indicated that there is no correlation between pain and EARR in response to OTM. Nevertheless, this result must be considered with caution, since it is supported by only one study. Additionally, other studies suggested different conclusions.[40-43,45] Studies on the correlation between pain and hyalinization in response to OTM were not found.

Orthodontic tooth movement is a result of alveolar remodeling through resorption and bone neoformation, as a consequence of inflammation stimulated by the application of mechanical forces, while pain is a characteristic symptom of inflammation. Besides, OTM is related to mechanical stimulation of free nerve endings as a result of application of mechanical forces to teeth.[7] The incidence of unwanted tissue damage in response to OTM, such as hyalinization of the periodontal ligament and EARR, is directly associated with the use of excessive mechanical force,[1,3-5] resulting in higher mechanical stimulation of free nerve endings and exacerbation of inflammation.

Although pain and unwanted tissue damage in response to OTM are related to mechanical stimuli and similar biological events, this study showed that the correlation between these variables is not fully elucidated yet. Based on the absence of clinical criteria for the establishment of optimal orthodontic mechanical forces, it is suggested that this issue needs further studies. Thus, orthodontic pain might be used as a clinical parameter to guide the use of biologically appropriate mechanical forces, minimizing the incidence of tissue damage during OTM.

CONCLUSION

There is not enough scientific evidence on the correlation between pain and unwanted tissue damage in response to OTM. This issue needs further studies, so that orthodontic pain may serve as one of the criteria for the use of biologically appropriate mechanical forces, contributing to reduced tissue damage during OTM.

The current concept of optimal orthodontic force, which is to promote maximum dental movement with minimum tissue damage, is quite subjective and marked by individual variability. In addition, during clinical practice, the orthodontist does not have technological resources or clinical parameters that allow evaluating the intensity of force applied to different areas of the periodontal ligament. One of the common clinical observations related to the application of orthodontic force is the patient report of pain. This article presents a systematic literature review, in which scientific evidence of the correlation between pain and tissue damage during orthodontic movement was studied, providing a scientific answer for the following question: Is pain reported by patients associated with application of inappropriate orthodontic force? Thus, it aims at aiding the orthodontist in the definition of clinical parameters for the use of optimal orthodontic force.

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