UNIVERSIDADE ESTADUAL DE CAMPINAS
FACULDADE DE ODONTOLOGIA DE PIRACICABA

LARISSA MOREIRA DE SOUZA

O USO DA TCFC NO DIAGNÓSTICO DE REABSORÇÃO RADICULAR EXTERNA E PERDA ÓSSEA LOCALIZADA EM SEGUNDOS MOLARES ADJACENTES A TERCEIROS MOLARES IMPACTADOS E AVALIAÇÃO DA ATIVIDADE DOS MÚSCULOS MASTIGATÓRIOS COMO FATOR DE RISCO PARA REABSORÇÃO RADICULAR EXTERNA

THE USE OF CBCT IN THE DIAGNOSIS OF EXTERNAL ROOT RESORPTION AND MARGINAL BONE LOSS IN SECOND MOLARS ADJACENT TO IMPACTED THIRD MOLARS AND THE EVALUATION OF MASTICATORY MUSCLES ACTIVITY AS A RISK FACTOR FOR EXTERNAL ROOT RESORPTION

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Orientadora: Profa. Dra. Luciana Asprino

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RESUMO

A presente tese teve, como um dos objetivos, revisar sistematicamente a literatura, de modo a avaliar se o uso da tomografia computadorizada de feixe cônico (TCFC), em comparação com avaliações feitas em radiografias panorâmicas, altera o diagnóstico de reabsorção radicular externa (RRE) e perda óssea localizada (POL), envolvendo um segundo molar adjacente a um terceiro molar impactado e também investigar se atividades orais não funcionais relacionadas ao bruxismo de vigília e a atividade dos músculos mastigatórios estariam relacionadas ao desenvolvimento de RRE em segundos molares inferiores. Para o primeiro estudo, uma revisão sistemática da literatura, foram aplicadas buscas estratégicas no *PubMed, EMBASE, Scopus, Web of Science, LILACS, Google Scholar, OpenGrey* e *ProQuest*. Estudos avaliando a detecção de RRE e/ou POL em um segundo molar adjacente a um terceiro molar impactado por meio de radiografia panorâmica (PAN) e TCFC foram incluídos. A prevalência e a concordância entre PAN e TCFC foram coletadas. O risco de viés foi avaliado usando o MAStARI. Foram identificados 593 artigos e, após seleção, 5 estudos foram incluídos. Em relação à RRE, sua prevalência na PAN foi de 5,31% a 19,5% e na TCFC foi de 22,8% a 62,0%. O percentual de concordância para detecção de RRE entre PAN e TCFC variou de 28,5% a 80,3%. Já a prevalência de POL variou de 21,9% a 62,9% na PAN, e de 21,6% a 80% na TCFC. A porcentagem de concordância variou de 66,0% a 85,0%. Assim, é possível concluir que a RRE e a POL são mais detectadas em exames de TCFC e existe uma concordância considerável entre a PAN e TCFC na detecção das duas condições, no entanto, está principalmente relacionada à ausência das patologias e não à sua presença. Para o segundo estudo, do tipo observacional transversal, 60 voluntários, que já tinham solicitação para realização de exame de TCFC para avaliação de terceiros molares inferiores, foram divididos em dois grupos: grupo RRE, composto por voluntários com RRE em pelo menos um segundo molar (n=30) e grupo controle (n=30), de acordo com as avaliações dos exames de TCFC, realizados com parâmetros de aquisição padronizados. Dados referentes ao bruxismo de vigília foram coletados por meio do OBC (*Oral Behaviors Checklist*) e complementados por meio de uma avaliação momentânea ecológica (AME). A eletromiografia de superfície (EMG) foi utilizada para avaliar a função dos músculos masseter e temporal anterior, bilateralmente. Todos os procedimentos foram realizados no mesmo dia. O grupo RRE apresentou mais comportamentos relacionados ao bruxismo de vigília do que o grupo controle, segundo OBC (p=0,027) e AME (p=0,035). Além disso, o grupo RRE demonstrou maior atividade eletromiográfica do que o grupo controle (p<0,05). Assim, atividades orais não funcionais relacionadas ao bruxismo de vigília, assim como uma maior atividade eletromiográfica dos músculos da mastigação tem relação com a presença de RRE em segundos molares adjacentes a terceiros molares impactados.

Palavras-chave: Bruxismo. Dente Impactado. Eletromiografia. Perda do osso alveolar. Radiografia Panorâmica. Reabsorção da Raiz. Terceiro Molar. Tomografia Computadorizada de Feixe Cônico.

ABSTRACT

The present study aimed to investigate whether the use of cone beam computed tomography (CBCT), compared to panoramic radiographic, alters the diagnosis of external root resorption (ERR) or marginal bone loss (MBL) involving a second molar adjacent to an impacted third molar, and to assess whether non-parafunctional activities related to awake bruxism and masticatory muscle activity may be risk factors for the development of ERR. A systematic review was carried out in PubMed, EMBASE, Scopus, Web of Science, LILACS, Google Scholar, OpenGrey, and ProQuest. Studies assessing the detection of ERR and/or MBL in a second molar adjacent to an impacted third molar, through CBCT and panoramic radiography (PAN) were included. Prevalence and agreement between PAN and CBCT on the detection of ERR and/or MBL were collected. The risk of bias was assessed using MAStARI. A total of 593 papers were identified, and after a 2-phase selection, 5 studies were included in the narrative synthesis. Regarding ERR, its prevalence in PAN was reported as from 5.31% to 19.5%, and in CBCT from 22.8% to 62.0%. The percentage of agreement varied from 28.5% to 80.3%. The prevalence of MBL varied from 21.9% to 62.9% in PAN, and from 21.6% to 80% in CBCT images. The percentage of agreement between PAN and CBCT for the detection of MBL ranged from 66.0% to 85.0%. There is considerable agreement between PAN and CBCT assessment of ERR and MBL, however, mostly related to the absence of the pathology rather than its presence. For the second study, a cross-sectional observational type, 60 patients, with a request for CBCT examination, were divided into two groups: ERR group, comprising patients with ERR in at least one second molar adjacent to an impacted mandibular third molar (n=30) and control group (n=30). Data regarding non-parafunctional activities related to awake bruxism were assessed through the Oral Behaviors Checklist (OBC) and a smartphone-based ecological momentary assessment (EMA). Surface electromyography (EMG) was used to assess masseter and anterior temporal muscle functions, bilaterally. The ERR group presented more activities related to awake bruxism than the control group, according to the OBC ($p=0.027$) and EMA ($p=0.035$). In addition, the ERR group showed higher EMG activity than the control group ($p<0.05$). Therefore, awake bruxism, as well as increased EMG activity of the masticatory muscles are related to the presence of ERR in second molars adjacent to impacted mandibular third molars.

Keywords: Alveolar Bone Loss. Bruxism. Cone-Beam Computed Tomography. Electromyography. Molar, Third. Radiography, Panoramic. Root Resorption. Tooth, Impacted.

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1 INTRODUÇÃO

Dentes impactados são aqueles que não irromperam completamente na cavidade oral, devido a um distúrbio em seu posicionamento na arcada, falta de espaço para erupção ou nas situações em que uma barreira física impediu a trajetória normal de erupção (Ghaeminia et al., 2016). Os terceiros molares são os dentes que mais sofrem impactação (Tassoker et al., 2019) e a prevalência média de impactação destes dentes na população mundial é de 24,4% (Carter; Worthinton, 2016).

Os terceiros molares, principalmente os inferiores, quando impactados pelos segundos molares, podem provocar lesão de cárie, reabsorção radicular externa (RRE) e perda óssea localizada (POL) na superfície distal dos segundos molares (Oenning et al., 2015; Kindler 2018; Tassoker et al., 2019)

A RRE ocorre no local de contato entre a raiz distal do segundo molar e a coroa do terceiro molar impactado, devido à pressão mecânica exercida por esse último (Oenning et al., 2018; Li et al., 2019). Estudos têm demonstrado, por meio da análise de elementos finitos, que o folículo dentário de um dente em desenvolvimento funciona como um mecanossensor que detecta a ação muscular e, como resultado, conduz o dente em direção à sua posição definitiva na cavidade oral (Sarrafpour et al., 2012; Sarrafpour et al., 2013). Porém, no caso de dentes impactados, o folículo dentário pode permanecer em contato com a raiz do dente adjacente e é comum o desencadeamento da RRE, um processo patológico, progressivo e irreversível (Alqerban et al., 2011).

Ainda, outro estudo com análise de elementos finitos mostrou que forças de mordida regulares resultam em vetores de alta dissipação de energia e áreas de tensão por compressão na raiz distal dos segundos molares adjacentes a terceiros molares impactados (Oenning et al., 2018). A força de mordida é um dos componentes da função mastigatória, que, por sua vez, é exercida pelos músculos mastigatórios (Castelo et al., 2008), principalmente os músculos masseter e temporal (Vilimek et al., 2016). Tais músculos podem ser afetados pela presença de atividades orais não funcionais, o que aumenta a frequência de mordidas e também a sua força (Bulut et al., 2018).

A falta de sintomas patognomônicos da RRE, muitas vezes, podendo ser uma condição assintomática, pode resultar em um diagnóstico tardio (Yi et al., 2017) e quando não detectada pelo cirurgião-dentista, a RRE pode evoluir, culminando em uma destruição considerável da estrutura dentária, necrose pulpar e, até mesmo, a perda do dente envolvido (Fuss et al., 2003).

Outra consequência da impactação de um terceiro molar por um segundo molar adjacente é o maior risco de prejudicar a saúde periodontal em tecidos ósseos nas regiões distais aos segundos molares, causando POL (Dias et al., 2020). Estudos realizados com imagens de tomografia computadorizada de feixe cônico (TCFC) mostraram que terceiros molares impactados em posições mesioinclinada e horizontal aumentam o risco de desenvolvimento de RRE e POL (Oenning et a., 2014; Oenning et al., 2015; Matzen et al., 2017; Dias et al., 2020).

A detecção da POL na região distal dos segundos molares é importante para determinar o prognóstico do segundo molar e decidir se há a necessidade de uma intervenção cirúrgica (Dias et al., 2020). De acordo com as diretrizes do Instituto Nacional para Excelência de Saúde e Cuidado (Londres), patologias irreversíveis como RRE moderadas e severas e POL nos segundos molares, relacionados a terceiros molares impactados, a presença de periapicopatias, cistos e tumores nos terceiros molares são indicativos para remoção do dente envolvido pela patologia (Nice et al., 2000).

Na prática clínica odontológica, a radiografia panorâmica tem sido o exame de primeira escolha para avaliar terceiros molares impactados e doenças associadas (Van der Linden et al., 1995; Radioation Protection, 2004). No entanto, condições como RRE e POL associadas aos segundos molares podem ser difíceis de serem detectadas, devido à sobreposição de imagens, ampliação e distorções inerentes à técnica da radiografia panorâmica (Hermann et al., 2019). Estudos utilizando imagens de TCFC consideraram que a prevalência de RRE pode ser 1,3 a 4,3 vezes maior neste exame do que nas avaliações baseadas em radiografias panorâmicas (Oenning et al., 2015; Matzen et al., 2017). Isso demonstra que, devido as suas vantagens de oferecer uma visualização tridimensional das estruturas, livre de sobreposições, ampliações ou distorções, a TCFC aumenta a detecção de RRE e POL (Matzen et al., 2017; Dias et al., 2020).

Apesar das vantagens da TCFC, o projeto SEDENTEX recomenda que radiografias convencionais (como as radiografias panorâmicas) devem, ainda assim, preceder a solicitação de TCFC, isto porque a dose de radiação ao qual um paciente é exposto em um exame de TCFC é maior do que em um exame de radiografia panorâmica (Peterson et al., 2015). Além disso, a Academia Europeia de Radiologia Dentomaxilo-facial publicou um posicionamento, onde afirma que o exame de TCFC para avaliação de terceiros molares inferiores só deve ser solicitada quando o cirurgião tem uma questão clínica específica que não pode ser respondida pela radiografia panorâmica e / ou radiografia intrabucal (Matzen et al., 2019). No entanto, patologias de segundos molares, como a RRE e a POL, não foram avaliadas ou mencionadas como uma dessas questões. Vale ressaltar que a própria remoção do terceiro molar como procedimento profilático ainda é um tema muito discutível (Tassoker et al., 2019).

A falta de sintomas patognomônicos e o difícil acesso à região de contato entre o terceiro molar impactado e o segundo molar adjacente podem resultar em um diagnóstico tardio dessas patologias, o que destaca a importância dos exames imagem no diagnóstico e da identificação de fatores de risco destas condições, para que o diagnóstico precoce seja estabelecido (Li et al., 2019).

Portanto, a presente tese teve, como um dos objetivos, revisar sistematicamente a literatura, de modo a avaliar se o uso da TCFC, em comparação com avaliações feitas em radiografias panorâmicas, altera o diagnóstico de reabsorção radicular externa (RRE) e perda óssea localizada (POL), envolvendo um segundo molar adjacente a um terceiro molar impactado e também investigar se atividades orais não funcionais relacionadas ao bruxismo de vigília e a atividade dos músculos mastigatórios estariam relacionadas ao desenvolvimento de RRE em segundos molares inferiores.

2 ARTIGOS

2.1 Comparison of panoramic radiography and CBCT for the assessment of external root resorption and marginal bone loss of second molar associated with third molar impaction: a systematic review.

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Larissa Moreira-Souza, Luciana Butini Oliveira, Hugo Gaêta-Araujo, Marcia Almeida-Marques, Luciana Asprino and Anne Caroline Oenning

ABSTRACT

Objective: To investigate whether the use of cone-beam computed tomography (CBCT) changes the diagnosis of external root resorption (ERR) or marginal bone loss (MBL) involving a second molar adjacent to an impacted third molar.

Methods: A systematic search was applied in PubMed, EMBASE, Scopus, Web of Science, LILACS, Google Scholar, OpenGrey, and ProQuest. Studies assessing the detection of ERR or MBL in a second molar adjacent to an impacted third molar through CBCT and panoramic radiography (PAN) were included. Prevalence and agreement between PAN and CBCT on the detection of ERR and MBL were collected. The risk of bias was assessed using the MAStARI.

Results: A total of 593 papers were identified, and after a 2-phase selection, 5 studies were included in the narrative synthesis. Regarding ERR, its prevalence in PAN was reported from 5.31% to 19.5% and from 22.8% to 62.0% in CBCT. The percentage of agreement varied from 28.5% to 80.3%. The prevalence of MBL varied from 21.9% to 62.9% in PAN, while those values varied from 21.6% to 80% in CBCT images. The percentage of agreement between PAN and CBCT for the detection of MBL ranged from 66.0% to 85.0%. Four studies presented low risk of bias and one had moderate risk.

Conclusions: More ERR and MBL are detected in CBCT compared to PAN. There is a considerable agreement between PAN and CBCT assessment of ERR and MBL, however, mostly related to the absence of the pathology rather its presence.

Keywords: Alveolar bone loss; Cone-beam computed tomography; Radiography, Panoramic; Root Resorption; Systematic review.

Introduction

A tooth is considered impacted when it remains inside the jaw's bone beyond the normal time for eruption[1] due to malposition, lack of space, or a physical obstacle in its eruption course.[2] As third molars are the most common impacted teeth[3], their removal is very frequent surgical procedure in dentistry.[4]

The impaction of a third molar can cause some pathological conditions,[2] such as external root resorption (ERR) in the second molar, marginal bone loss (MBL) of the distal surface of the second molar, and cystic lesion related to the third molar.[5] The sensible point is that the pathological conditions associated to impacted third molars might evolve without clinical signs and symptoms .[4,6]

Despite the cause-effect relationship is not completely clear, it seems that the mechanical force of an impacted tooth triggers ERR in an adjacent one in addition to the inflammation of the periodontium around this tooth.[7] Moreover, it seems logical that a misplaced and non-erupted tooth may predispose the MBL, that is the destruction of bone.[4] Depending on the severity of these conditions, however, the patient may be asymptomatic;[8] thus ERR and MBL of the second molars are frequently and solely detected on radiographic examinations that precedes removal of third molars.[5]

Radiographic images provide information about the third molar itself, the surrounding bone, the adjacent tooth and anatomical structures.[9] Panoramic radiography (PAN) is the first-choice method for assessment of third molars and for treatment planning.[2,4,9] This imaging modality, however, offers a two-dimensional image, which involves several potential sources of misinterpretation, such as image magnification, distortion by projection errors, blurred images, and complex maxillofacial structures projected onto a two-dimensional plane.[10] On the other hand, cone beam computed tomography (CBCT) offers the possibility of sectioning the volume in all three planes without distortion to detect small details.[4] Although the possibility of adjusting exposure parameters and field of view to optimize the radiation dose according to the diagnostic requirements,[2] CBCT units still provide higher radiation doses to the patient in comparison to PAN.[9] For this reason, the discussion on when performing CBCT prior to surgical removal of third molars remains a hot-topic. The European Academy of DentoMaxilloFacial Radiology (EADMFR) has published a position paper which stated that CBCT-imaging of the mandibular third molar should only be requested when the surgeon has a specific clinical question that cannot be answered by PAN and/or intraoral imaging. [11] However, second molar pathologies - ERR and MBL - were not assessed or mentioned as one of these questions.

When ERR and MBL in the second molars are early and correctly diagnosed, the consequences of these pathological conditions are reduced or ceased. In some cases, such as the presence of a severe ERR in the second molar, removal of the second molar should be considered instead of the third molar.[5] There is no clinical protocol, however, guiding to remove the second instead of the third molar.[5] It is worth mentioning that the removal a third molar itself as a prophylactic procedure is still a very debatable topic.[3]

Despite the importance of correct diagnosis of ERR and MBL in order to avoid clinical complications, the scope of these conditions is not established yet. This systematic review (SR) aimed to assess whether the use of CBCT changes the diagnosis of ERR and MBL involving a second molar adjacent to an impacted third molar.

Methods

The protocol of this SR was developed following recommendations of PRISMA and the study protocol was registered at the Prospective Register of Systematic Reviews (PROSPERO), available under registration number CRD42020136588.[12]

This SR was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Checklist (PRISMA)[13] and Synthesis Without Meta-analysis (SWiM) reporting items.[14]

Information sources

Initially, the following review question was used to establish a search strategy: Is the use of CBCT determinant for the evaluation of ERR or MBL involving a second molar adjacent to an impacted third molar?

An appropriate search strategy was developed for each of the following electronic database with the support of a heath science librarian. Strings of search terms were constructed, consisting of relevant text words and Boolean links: PubMed: ("Root Resorption"[MeSH] OR "Resorption" OR "Resorptions" OR "alveolar bone loss"[MeSH Terms] OR "alveolar bone loss" OR "Alveolar Bone Losses" OR "Alveolar Process Atrophy" OR "Alveolar Process Atrophies" OR "Periodontal Bone Losses" OR "Periodontal Bone Loss" OR "Alveolar Bone Atrophy") AND ("Radiography, Panoramic"[MeSH] OR "Panoramic Radiography" OR "Panoramic Radiographies" OR "panoramic image" OR "panoramic images" OR "panoramic imaging" OR "panoramic radiograph" OR "panoramic radiographs" OR "panoramic X-ray" OR "panoramic" OR "Pantomography" OR "Pantomographies" OR "Orthopantomography" OR "Orthopantomographies") AND ("cone-beam computed tomography"[MeSH Terms] OR "CBCT" OR "Cone-Beam" OR "conebeam"). The full search strategy developed for each of the electronic database is detailed in Appendix 1.

The literature search was done within the PubMed, EMBASE, Scopus, Web of Science and Latin American and Caribbean Health Sciences (LILACS), until January 24th, 2021. Grey literature was searched on Google Scholar, OpenGrey and ProQuest Dissertations & Theses Global.

All references were managed by Mendeley software (Mendeley Ltd., London, UK) and duplicate hits removed. There were no restrictions regarding language or publication period.

Eligibility criteria

Studies assessing the detection and prevalence of ERR or MBL of second molar adjacent to an impacted third molar through PAN and CBCT were included. Reviews, case reports, letters and personal opinions were excluded.

Study selection and data collection

A two-phase process was adopted to study selection. First, two reviewers (L.M.S. and M.A.M.) read titles and abstracts and after the full texts of the selected ones. The first and second reviewers (L.M.S. and M.A.M.) performed the study selection independently. A third reviewer (A.C.O.) and a fourth reviewer (L.B.O) were consulted in the event of a disagreement between the first and second authors.

For data extraction, at first two reviewers independently collected the data and compared it afterwards. A third reviewer, an experienced radiologist, confirmed the extracted data (A.C.O.).

The following information was collected: author, year, country, sample size, outcomes, associated parameters, imaging acquisition parameters, statistical analysis, prevalence of ERR and MBL, and agreement between PAN and CBCT, other findings and authors' main conclusions.

Risk of bias in individual studies

The methodological quality of the included studies was assessed using the risk-of-bias tool Meta-Analysis of Statistical Assessment and Review Instrument (MAStARI) from the Joanna Briggs Institute (Institute Joanna Briggs Institute Reviewers' Manual).[15] The evaluation was estimated by three authors (L.M.S, H.G.A and A.C.O) regarding the proportion of "yes" items as follows: high (up to 49% score "yes"), moderate (50–69% score "yes"), and low (>70% score "yes"). In addition, the online tool *robvis* (Risk-of-bias VISualization) was used to generate figures.[16]

Synthesis of the results

Heterogeneity within studies was assessed based on study characteristics, methodological and outcome characteristics. All the included studies presented the data collected; however, they were not grouped together in meta-analysis due to the methodological disparities.

Results

Study selection

The search identified 593 records and after removing duplicates, 486 remained, being 12 selected to full-text analysis. In total, five studies were included in the narrative synthesis.[2,8,17-19] Further information about the 7 excluded studies is available in Appendix 2. The studies' selection steps are presented in a detailed flowchart diagram in Figure 1.

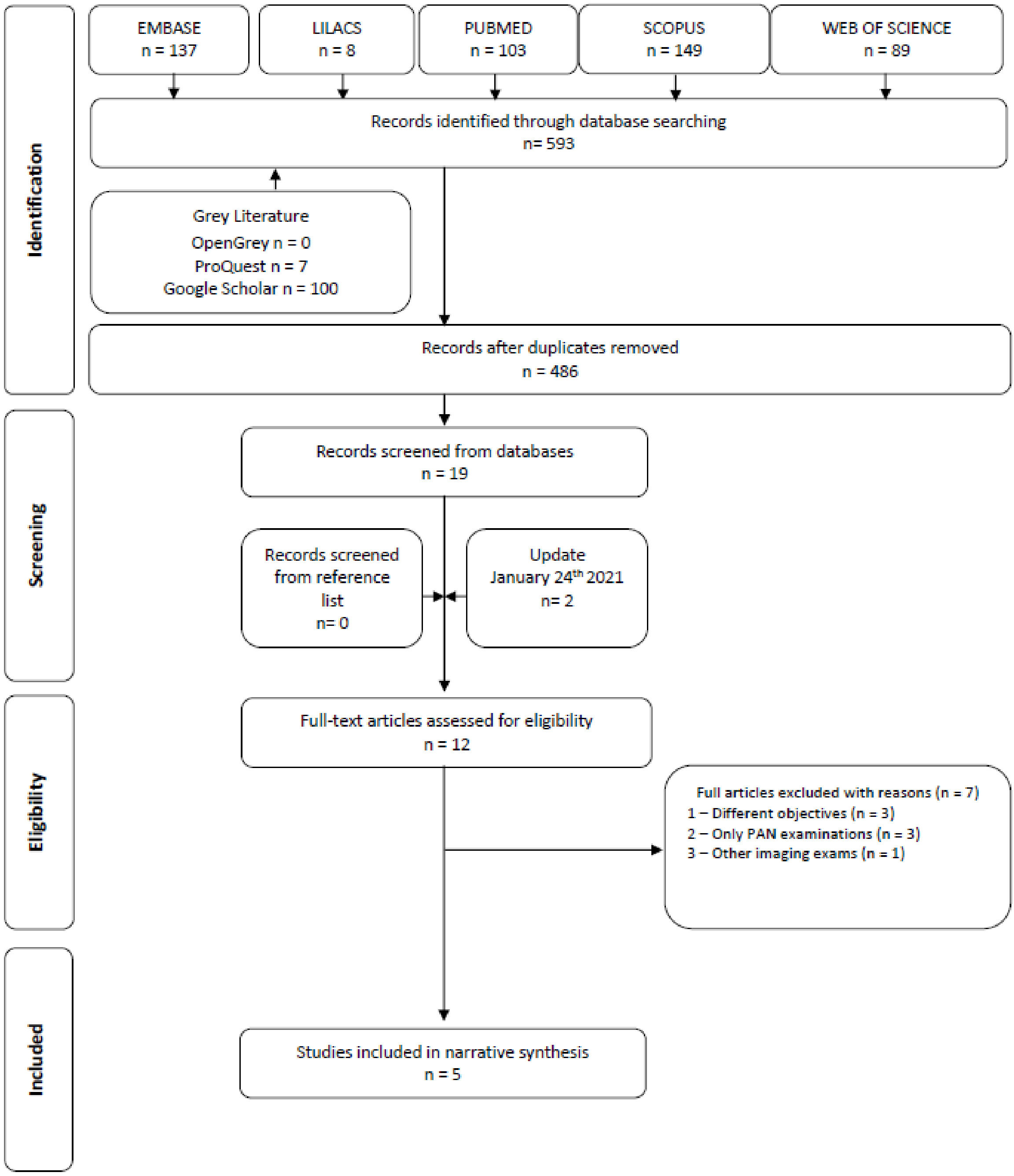

Figure 1 Flow diagram of literature search and selection criteria.

Study characteristics

Studies were conducted from 2014[2] to 2020[18,19] (Table 1). All studies retrospectively retrieved patients presenting both imaging modalities from imaging data banks. Two studies evaluated the prevalence and agreement of ERR through PAN and CBCT images,[2,8] one study evaluated the agreement of ERR through PAN and CBCT images,[19] one study evaluated the prevalence and agreement of MBL through PAN and CBCT images, [18] one study evaluated the prevalence and agreement of both ERR and MBL through the same imaging exams.[17]

Table 1 Summary of descriptive characteristics of included articles that compared panoramic radiography (PAN) and CBCT for detection of pathology on second molar associated with third molar impaction: external root resorption (ERR) and marginal bone loss (MBL) (n=5)

Author, year, country	**Sample size**	**Outcomes**	**Associated parameters**	**Imaging acquisition parameters**	**Statistical Analysis**	**Main findings (Prevalence and agreement between PAN and CBCT)**	**Other Findings**	**Main conclusions**
Oenning et al, 2014, Brazil	188 3rd molars (91 maxillary and 97 mandibular)	ERR in 2nd molars	1. Inclination of 3rd molar (Winter classification) *vs* ERR	PAN: OP100 D (Instrumentarium) operating at 66kVp, 2.5mA, exposure time of 17.6s CBCT: Classic i-CAT (Imaging Sciences International) operating at 120kVp, 6mA, 0.25mm voxel size, 13cm FOV	X^2 test Fisher exact test 2-proportion Z test	Prevalence of ERR: PAN 5.31%, CBCT 22.88% Total agreement: 151 cases (80.3%) ERR presence: 8 (4.3%) ERR absence: 143 (76%)	1. Mandibular 3rd molars in mesioangular and horizontal inclinations were more likely to cause ERR on 2nd molars.	A significantly greater number of cases of ERR was detected using CBCT. When direct contact between the 2nd molar and an unerupted mandibular 3rd molar is observed on PAN, especially in mesioangular or horizontal 3rd molars, CBCT should be used to provide better evaluation.

Author, year, country	Sample size	Outcomes	Associated parameters	Imaging acquisition parameters	Statistical Analysis	Main findings (Prevalence and agreement between PAN and CBCT)	Other Findings	Main conclusions
D'Costa et al, 2017, India	120 3rd molars (39 maxillary and 81 mandibular)	ERR in 2nd molars	1. Location and severity of ERR 2. Grading of ERR (Nemcovsky criteria) 3. Position of 3rd molar (Pell & Gregory ABC classification)	Not mentioned	Chi-squared test McNemar test	Prevalence of ERR: PAN 13.3%, CBCT 52.5% Total agreement: 71 cases (59%) – ERR presence: 15 (12.5%); ERR absence: 56 (46.5%)	1.Location of ERR: Cervical>Middle>Apical Severity: Slight>Moderate 2.Grade: gradeA>gradeB>gradeC 3. Position B is more prevalent. Sensitivity 23.8% and Specificity 98.2% (CBCT as a gold standard and PAN as a parameter).	ERR was "better" detected with CBCT. If on PAN a close contact is detected between the impacted 3rd molar and adjacent 2nd molar, CBCT can be advised considering the "risk vs reward ratio."
Matzen et al, 2017, Denmark	379 mandibular 3rd molars	ERR and MBL at the 2nd	1. Frequency of removal based on	PAN: Cranex Tome (Soredex) or ProMax	Descriptive statistics: Percentage of	Prevalence of ERR: PAN 16%-19.5%, CBCT	1.Frequency of removal decision based on pathologies: PAN 47%,	ERR and MBL in the 2nd molars are more often observed in

Author, year, country	Sample size	Outcomes	Associated parameters	Imaging acquisition parameters	Statistical Analysis	Main findings (Prevalence and agreement between PAN and CBCT)	Other Findings	Main conclusions
		molars	pathological findings 2. interobserver reproducibility 3. factors in PAN that could predict ERR and MBL in CBCT (e.g., location of overprojection, 3rd molar inclination)	(Planmeca) CBCT: NewTom 3G (QR SRL) operating at 0.3mm voxel size, 6x8cm FOV or Scanora 3D (Soredex) operating at 0.13mm voxel size, 6x6cm FOV	agreement, frequency of removal (PAN, CBCT *vs* pathology) Interobserver reproducibility: percentage of accordance and Kappa Logistic regression	22.4%-62% Prevalence of MBL: PAN 21.9% - 55.6%, CBCT 21.6%-74% Agreement PAN/CBCT: ERR 54-74%, MBL 66-85% (varied among 4 observers)	CBCT 65% 2. percentage of accordance: PAN 28.1% - 99.7%, CBCT 61% - 97.4%. Kappa: poor to excellent 3. Mesioangulated / horizontally positioned 3rd molars overprojecting the cervical part of the 2nd molar in PAN are strongly associated with pathology observed in CBCT.	CBCT than in PAN. More third molars would be removed if pathological findings are based on CBCT.
Dias et al., 2020,	124 mandibular	MBL at the 2nd	1. Third molar angulation	PAN: OP200 (Instrumentarium)	McNemar test , Kappa	Prevalence of MBL: PAN	1. Mesioangular and horizontal 3rd molars	Diagnosing 2nd molar MBL associated to

Author, year, country	Sample size	Outcomes	Associated parameters	Imaging acquisition parameters	Statistical Analysis	Main findings (Prevalence and agreement between PAN and CBCT)	Other Findings	Main conclusions
Uruguay	3rd molars	molars	2. severity of the MBL /age	operating at 66kVp, 8mA, exposure time of 14s CBCT: i-CAT (Imaging Sciences International) operating at 120kVp, 36mA, 0.25mm voxel size, 16x13cm FOV	statistics, Bowker test, Fisher's exact test	62.9%, CBCT 80% Agreement PAN – CBCT: MBL 74.2%	had a significant association with MBL of the adjacent 2nd molars 2. PAN underestimated the severity of MBL compared to CBCT / the mean age of patients with severe MBL was higher	impacted 3rd molar in PAN may be chal-lenging because of false negatives. Impacted 3rd molars justify preoperative CBCT scans if 2nd molar MBL needs to be assessed.
Mendonça et al., 2020, Brazil	221 mandibular 3rd molars	ERR in 2nd molars and contact area	1. Comparison between PAN and CBCT evaluation	PAN: PaxX-400C (Vatech) CBCT: i-CAT	Percentage agreement, McNemar test, logistic	Prevalence of ERR: PAN 10.00%, CBCT 22.40%	1. The diagnostic change regarding 2nd molar ERR after CBCT evaluation was not capable of	Diagnostic changes of the 3rd molar relationship with adjacent structures do

Author, year, country	Sample size	Outcomes	Associated parameters	Imaging acquisition parameters	Statistical Analysis	Main findings (Prevalence and agreement between PAN and CBCT)	Other Findings	Main conclusions
		between 2nd and 3rd molars	2. Changes in diagnosis after CBCT evaluation and the impact in the surgical planning and post-operative complication expectation	FLX (Imaging Sciences International) operating at 120kVp, 36.12mAs, 0.25mm voxel size	regression analysis	Agreement PAN – CBCT: ERR 28.5%	altering the surgical planning 2. EER in the 2nd molar and contact area with the 3rd molar assessed by CBCT seems to decrease expectation of post-operative complications	not change the decision to remove the tooth, but may alter the intraoperative procedures

Risk of bias in the studies

Four studies were considered to have a low risk of bias and one had a moderate risk of bias (Figure 2A and B). In 3 studies the risk of bias was judged low for all domains. It is important to emphasize that only one study[19] obtained score “not applicable”, which occurred in two domains (D5 and D6).

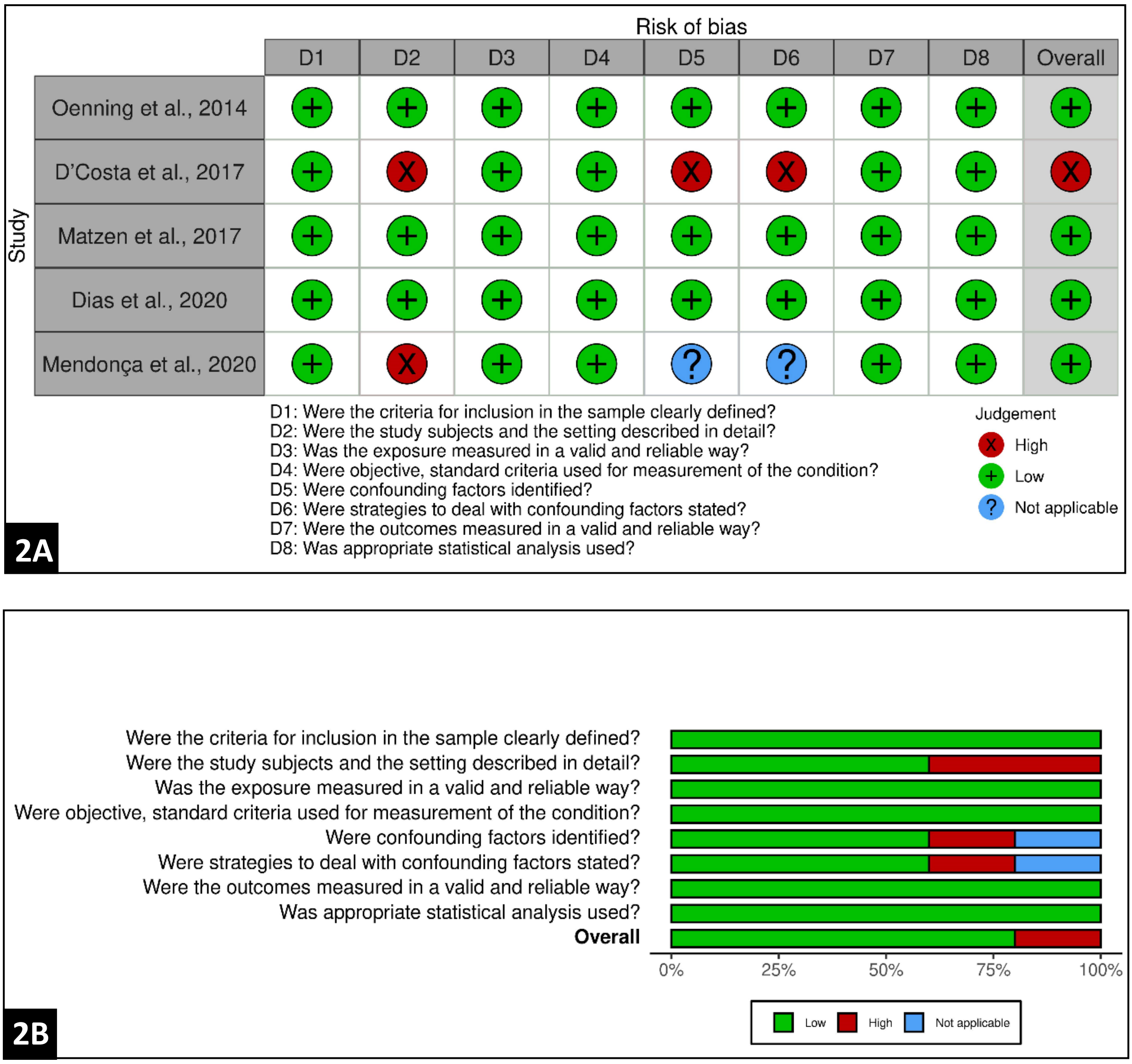

Figure 2 RoB summary of author's judgments for each included study, evaluated by the MAStARI tool and graphically represented by “Traffic-light” plot (A) and Weighted bar plot (B) (generated using the online tool robvis (Risk-Of-Bias VISualization).

Results of individual studies

The included studies evaluated from 120[8] to 379[17] teeth. Two studies evaluated maxillary and mandibular third molars[2,8] and three studies evaluated mandibular third molars only.[17,18,19] From the five included studies, two reported prevalence and agreement in the detection of ERR between PAN and CBCT images[2,8] and one reported only the agreement in the detection of ERR between these imaging exams.[19] From these five studies, one reported prevalence and agreement for the detection of MBL in PAN and CBCT images[18] and one reported prevalence and agreement for the detection of both ERR and MBL through these PAN and CBCT images.[17] One study also reported sensitivity and specificity of PAN for ERR detection considering CBCT as reference standard.[8]

The prevalence of ERR for maxillary and mandibular second molars varied from 5.3%[2] to 13.3%[8] in PAN, while those values varied from 22.9%[2] to 52.5%[17] in CBCT images. Only one study[2] disclosed the prevalence of ERR in maxillary second molars, which was 1% in PAN and 14.3% in CBCT. Three studies assessed the mandibular second molars separately, and the reported prevalence varied from 9.3%[2] to 19.5%[17] in PAN, and from 22.4%[17,19] to 62%[17] in CBCT (Table 2). Data on prevalence of one study[19] was not available and was retrieved directly with the authors. The percentage of agreement among observers between PAN and CBCT for the detection of ERR was between 28.5%[19] and 80.3%[2] (Table 1).

Table 2 Comparison between panoramic radiograph (PAN) and cone beam computed tomography (CBCT) images in the detection of external root resorption in second molars (2M)

	Maxillary and mandibular 2M (%)	**Maxillary 2M (%)**	**Mandibular 2M (%)**

	PAN	CBCT	PAN	CBCT	PAN	CBCT
Oenning et al., 2014	5.3	22.9	1	14.3	9.3	31
Matzen et al., 2017	-	-	-	-	16-19.5	22.4-62
D'Costa et al., 2017	13.3	52.5	-	-	-	-
Mendonça et al., 2020	-	-	-	-	10	22.4

Missing values marked with "-" mean that authors did not assess this variable.

	Maxillary and mandibular 2M (%)		Maxillary 2M (%)		Mandibular 2M (%)	
	PAN	CBCT	PAN	CBCT	PAN	CBCT
Matzen et al., 2017	-	-	-	-	21.9 - 55.6	21.6 - 74
Dias et al., 2020	-	-	-	-	62.9	80

Regarding the MBL, the included studies assessed its prevalence only in mandibular second molars which in PAN was reported between 21.9%[17] to 62.9%[18]. In CBCT images, the prevalence of MBL of mandibular second molars varied from 21.6%[17] to 80%[18] (Table 3). The percentage agreement between these imaging modalities varied from 66.0% to 85.0%[17] (Table 1).

Table 3 Comparison between panoramic radiograph (PAN) and cone beam computed tomography (CBCT) images in the detection of marginal bone loss of second molars (2M)

	ERR	MBL

Missing values marked with "-" mean that authors did not assess this variable.

Table 4 shows that three studies found a relation between ERR and MBL of mandibular second molars and the mesioangular and horizontal angulation of mandibular third molars.[2,17,18]

	Angulation of 3M		Angulation of 3M	
	Maxilla	**Mandible**	**Maxilla**	**Mandible**
Oenning et al., 2014	-	Mesioangular / horizontal	-	-
Matzen et al., 2017	-	Mesioangular / horizontal	-	Mesioangular / horizontal
D'Costa et al., 2017	-	-	-	-
Dias et al., 2020	-	-	-	Mesioangular / horizontal
Mendonça et al., 2020	-	-	-	-

Table 4 Relation of external root resorption (ERR) and marginal bone loss (MBL) of second molars and inclination of third molars (3M) in CBCT images

Missing values marked with "-" mean that authors did not assess this variable.

Discussion

Analyzing potential pathological consequences on the second molar is an important step of the third molar imaging assessment. The detection of ERR and MBL involving the second molar might have a significant impact in the treatment decision.[19] In this context the results of this SR have shown that ERR in second molars adjacent to an impacted third molar was reported to be from 5.3% to 19.5% in PAN while on CBCT images the prevalence of ERR was reported between 22.8% and 62%.[2,8,17] A clear increase in ERR prevalence (i.e., detection) is observed in CBCT-based evaluation of the relationship of second and third molars. This tendency of more ERR detection on CBCT images have been previously discussed,[17] indicating that the three-dimensional volume sectioning analysis, without magnification or distortion, allow this better detectability. In addition to that, the possibility to verify the suspicion of root resorption in more than two planes, without superimposition of adjacent structures, plays a significant role in greater detection for CBCT.[2,17] On the contrary, PAN assessment is restricted to a two-dimensional image prone to magnification, distortion, and third molar image projection over the second molar, precluding the detection of root surface contour alterations related to the ERR.[2]

Regarding MBL prevalence, two included studies showed this data. Matzen et al.[17] reported a prevalence of MBL in PAN images from 21.9% to 55.6%, while on CBCT this prevalence was from 21.6% to 74%. Dias et al.[18] reported a 62.9% MBL prevalence in PAN and 80% in CBCT images. In contrast to ERR, for MBL the difference in prevalence between PAN and CBCT may be considered just moderately higher for the last. The advantages of three-dimensional modality over two-dimensional imaging, however, also applies here for the higher MBL detection in CBCT images.[17,18] For example, in PAN image the superimposition of the buccal and lingual cortical plates may smooth or cover the MBL which is clearly observed in the sectional CBCT assessment.

The sample of all included studies was randomly selected, which is important when considering the prevalence of those conditions. Only one study has reported the prevalence of ERR in maxillary second molars, that was markedly lower in PAN (1%) compared to CBCT (14.3%).[2] Two studies found an association between mandibular third molar angulation (i.e., mesioangular or horizontal) and the detection of ERR, but none for maxillary molars.[2,17] That same association was reported for MBL in mandibular molars[17,18]; none of the studies reported the prevalence of MBL in maxillary second molars. A previous study[20] assessed MBL and ERR in maxillary second molars comparing PAN and CBCT images. In this study only the patients who presented a suspicion of pathologies in PAN (MBL, ERR, or increased follicular space) were scanned with CBCT. As we understood that it could change the agreement scenario and the prevalence data could not be extracted, this study was not included in the SR. Nevertheless, the authors report similar detection rates of second molar pathology in both imaging modalities, although PAN may underestimate ERR.

Overall, the studies included in the present SR presented low risk of bias, with exception of one study. The 7th domain regarding the outcome measure was considered positive for all studies. A previous systematic review on CBCT accuracy for ERR[21] indicates CBCT as a reliable method for ERR detection, although the included studies were *in vitro* with simulated ERR lesions. In addition, the indication of further CBCT investigation in cases when ERR is suspected in PAN may change the treatment planning.[5] On the other hand, Schröder et al.[22] assessed CBCT accuracy for natural ERR detection from 2.4 to 3.1 mm^3 and concluded that CBCT may not be as accurate as previous *in vitro* studies have claimed. For periodontal bone loss evaluation CBCT is a well-established method.[23] Nevertheless, data on prevalence of ERR and MBL are reported considering the observers in each study and may diverge if different observers do the same evaluations, mainly for ERR. Thus, it is expected a moderate-to-high observer variation on the imaging-based detection of discrete pathologies, due to the inherent subjectivity of the task, observers' experience, and observers' formation background.

In this systematic review, we also aimed at verifying the agreement between PAN and CBCT regarding the detection of ERR and MBL involving second molars adjacent to impacted third molars. The agreement between imaging modalities for ERR was reported between 28.5% and 80.3%,[2,8,17,19] while for MBL it was between 66% and 85%.[17,18] Overall agreement shows slightly higher percentage for MBL. As stated by Dias et al.,[18] this fair agreement for MBL could not be the same when dealing with more detailed diagnostic tasks such as ERR.

Although the studies showed a relatively high agreement between PAN and CBCT for ERR detection, this is mostly related to the number of second molars classified with absence of ERR. For example, in the study of Oenning et al.[2] the agreement for presence of ERR occurred in 4.3%, while in 76% for the absence of ERR. Matzen et al.[17] found agreement for MBL presence of 24% while the agreement was 51.6% for MBL absence, considering all 4 observers together. Conversely, Dias et al.[18] found higher agreement for MBL presence (58.9%) compared to MBL absence (15.3%). Such controversial results between those studies may be related to the methodological issues regarding image analysis: while one study invited four oral radiologists to independently assess the images,[17] the latter invited two oral radiologists to assess the images in consensus.[18]

Apart from prevalence and agreement between PAN and CBCT for the detection of ERR and MBL, the included studies also revealed additional outcomes. ERR lesions are usually located in the cervical portion of the root of second molars, and, considering CBCT as reference standard, PAN images have low sensitivity (0.238) and high specificity (0.982) for ERR diagnosis.[8] Oenning et al.[2] and Dias et al.[18] concluded that mandibular third molars in mesioangular and horizontal inclinations have a greater potential to induce ERR and MBL on the adjacent second molars, respectively, which corroborated the findings of Matzen et al.[17] In addition, PAN tends to underestimate MBL severity compared to CBCT.[18] The frequency of removal decision of the third molars are increased when assessing CBCT images,[17] although the diagnostic change specifically in ERR presence caused by the CBCT evaluation is not capable of altering the surgical planning.[19]

The diagnostic efficacy of imaging exams can be classified according to the hierarchical model proposed by Fryback and Thornbury.[24] In this 6-level model, the first level concerns technical aspects, the second level is directed to diagnostic accuracy, sensitivity and specificity of the images, the third level addresses the capability of the images to change one's diagnostic thinking, the fourth level regards the treatment plan change, the fifth level measures the effect on patient outcome, and the sixth and last level analyzes societal benefit of the imaging exam. In this sense, the studies included in the present systematic review may partially cover levels 1 to 3 of this model.

Limitations

CBCT assessment showed a higher prevalence of both ERR and MBL compared to PAN images. However, due to the retrospective nature of the included studies, none followed-up the patients or used a gold-standard to confirm the presence of such pathologies, and thus, the diagnostic values (accuracy, sensitivity, and specificity) could not be determined for CBCT and PAN in ERR and MBL diagnosis. Although this could be considered a limitation, the applicability of a gold standard in clinical studies assessing ERR and MBL may be restricted for ethical reasons (e.g., the extraction of the second molar for histology analysis to confirm ERR). In addition, CBCT has proven its value in ERR detection, and this imaging modality has capability to diagnose clinically relevant ERR in the second molars.

Matzen et al.[17] discussed such issue, stating that CBCT could not be considered as the gold standard. This does not invalidate the studies, but when analyzing the results, one must bear in mind that prevalence of ERR and MBL in PAN and CBCT images does not mean the diagnostic accuracy of these imaging modalities for such tasks. Thus, the prevalence reported is imaging modality and observer dependent. As none of the studies assessed observer experience, future studies should be directed to elucidate the relationship between the imaging modalities (PAN and CBCT) and observer experience (juniors versus seniors, or different specialists) in the prevalence of ERR and MBL of second molars adjacent to impacted third molars.

CBCT images may vary significantly depending on CBCT machine, technical specifications, and acquisition parameters; thus, it has been recommended to not just extrapolate results from one CBCT unit to another.[25] For the detection of fine small, detailed structures (or pathologies), high-resolution scans are recommended[10] which are, not only but also, related to the voxel size of the scanning. The voxel size used for scanning in the include studied varied from 0.13 to 0.3mm, which may be adequate for ERR detection.[26] From a clinical perspective, however, superficial (very small) resorptions, which would demand high resolution CBCT protocols, in general, do not impact the management of an impacted third molar. In other words, the treatment planning is potentially changeable when the resorptive lesion compromises the dentine. The same reasoning can be applied for bone loss extension, with the difference that the clinical impact is more related to the prognosis definition than the treatment plan. On this matter, we understand that standard protocols and restricted fields of view can represent the optimal strategies to balance dose and image quality for this diagnostic task, given that higher resolution scans usually require higher radiation doses delivered to the patient.

Conclusion

It seems reasonable to affirm that a two-dimensional exam is always the first choice to assess third molars. However, CBCT may be indicated if there is suspicion of ERR in the adjacent tooth, as there is a significant increase in the detection of this condition in CBCT. Regarding MBL, although CBCT also provides greater detection, it is not too expressive. Therefore, after PAN examination, whether ERR is suspected in a second molar adjacent to a mesioangular or horizontal third molar, it is recommended to acquire a CBCT for better evaluation.

Moreover, there is a considerable agreement between PAN and CBCT on the assessment of ERR and MBL, though those are usually related to the agreement in the absence of the pathology rather its presence. Still, studies aiming at the higher levels of diagnostic efficacy (e.g., diagnostic thinking and treatment planning) of CBCT in comparison to PAN related to the detection of ERR and MBL of second molar adjacent to impacted third molar must be carried out to further elucidate this research topic.

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APPENDIX 1

SEARCH STRATEGIES

PubMed: ("Root Resorption"[Mesh] OR "Resorption" OR "Resorptions" OR "alveolar bone loss"[MeSH Terms] OR "alveolar bone loss" OR "Alveolar Bone Losses" OR "Alveolar Process Atrophy" OR "Alveolar Process Atrophies" OR "Periodontal Bone Losses" OR "Periodontal Bone Loss" OR "Alveolar Bone Atrophy") AND ("Radiography, Panoramic"[Mesh] OR "Panoramic Radiography" OR "Panoramic Radiographies" OR "panoramic image" OR "panoramic images" OR "panoramic imaging" OR "panoramic radiograph" OR "panoramic radiographs" OR "panoramic X-ray" OR "panoramic" OR "Pantomography" OR "Pantomographies" OR "Orthopantomography" OR "Orthopantomographies") AND ("cone-beam computed tomography"[MeSH Terms] OR "CBCT" OR "Cone-Beam" OR "conebeam")

SCOPUS: TITLE-ABS-KEY(("Resorption" OR "Resorptions" OR "alveolar bone loss" OR "Alveolar Bone Losses" OR "Alveolar Process Atrophy" OR "Alveolar Process Atrophies" OR "Periodontal Bone Losses" OR "Periodontal Bone Loss" OR "Alveolar Bone Atrophy") AND ("Panoramic Radiography" OR "Panoramic Radiographies" OR "panoramic image" OR "panoramic images" OR "panoramic imaging" OR "panoramic radiograph" OR "panoramic radiographs" OR "panoramic X-ray" OR "panoramic" OR "Pantomography" OR "Pantomographies" OR "Orthopantomography" OR "Orthopantomographies") AND ("Cone-Beam" OR "conebeam" OR "CBCT"))

Web of Science: (("Resorption" OR "Resorptions" OR "alveolar bone loss" OR "Alveolar Bone Losses" OR "Alveolar Process Atrophy" OR "Alveolar Process Atrophies" OR "Periodontal Bone Losses" OR "Periodontal Bone Loss" OR "Alveolar Bone Atrophy") AND ("Panoramic Radiography" OR "Panoramic Radiographies" OR "panoramic image" OR "panoramic images" OR "panoramic imaging" OR "panoramic radiograph" OR "panoramic radiographs" OR "panoramic X-ray" OR "panoramic" OR "Pantomography" OR "Pantomographies" OR "Orthopantomography" OR "Orthopantomographies") AND ("Cone-Beam" OR "conebeam" OR "CBCT"))

EMBASE: (("Resorption" OR "Resorptions" OR "alveolar bone loss" OR "Alveolar Bone Losses" OR "Alveolar Process Atrophy" OR "Alveolar Process Atrophies" OR "Periodontal Bone Losses" OR "Periodontal Bone Loss" OR "Alveolar Bone Atrophy") AND ("Panoramic Radiography" OR "Panoramic Radiographies" OR "panoramic image" OR "panoramic images" OR "panoramic imaging" OR "panoramic radiograph" OR "panoramic radiographs" OR "panoramic X-ray" OR "panoramic" OR "Pantomography" OR "Pantomographies" OR "Orthopantomography" OR "Orthopantomographies") AND ("Cone-Beam" OR "conebeam" OR "CBCT"))

LILACS: (tw:("Resorption" OR "Resorptions" OR "alveolar bone loss" OR "Alveolar Bone Losses" OR "Alveolar Process Atrophy" OR "Alveolar Process Atrophies" OR "Periodontal Bone Losses" OR "Periodontal Bone Loss" OR "Alveolar Bone Atrophy" OR "Reabsorção" OR "Reabsorção Óssea" OR "Reabsorção da Raiz" OR "Perda do Osso Alveolar" OR "Perda Óssea Osteoclástica" OR "Osteoclasia" OR "Resorción Ósea" OR "Resorción Ósea" OR "Resorción Radicular" OR "Pérdida de Hueso Alveolar")) AND (tw:("Panoramic Radiography" OR "Panoramic Radiographies" OR "panoramic image" OR "panoramic images" OR "panoramic imaging" OR "panoramic radiograph" OR "panoramic radiographs" OR "panoramic X-ray" OR panoramic* OR "Pantomography" OR "Pantomographies" OR "Orthopantomography" OR "Orthopantomographies" OR "Radiografia Panoramica" OR "Radiografias Panorâmicas" OR "raio x panorâmico" OR "Ortopantomografia" OR "Pantomografia")) AND (tw:("Cone-Beam" OR "conebeam" OR "CBCT" OR "Tomografia Computadorizada de feixe cônico" OR "feixe cônico" OR "Tomografía Computarizada de Haz Cónico" OR "Haz Cónico")) AND (instance:"regional") AND (db:("LILACS"))

Proquest Dissertation & Theses: noft(("Resorption" OR "Resorptions" OR "alveolar bone loss" OR "Alveolar Bone Losses" OR "Alveolar Process Atrophy" OR "Alveolar Process Atrophies" OR "Periodontal Bone Losses" OR "Periodontal Bone Loss" OR "Alveolar Bone Atrophy") AND ("Panoramic Radiography" OR "Panoramic Radiographies" OR "panoramic image" OR "panoramic images" OR "panoramic imaging" OR "panoramic radiograph" OR "panoramic radiographs" OR "panoramic X-ray" OR "panoramic" OR "Pantomography" OR "Pantomographies" OR

"Orthopantomography" OR "Orthopantomographies") AND ("Cone-Beam" OR "conebeam" OR "CBCT"))

OpenGrey: (("Resorption" OR "Resorptions" OR "alveolar bone loss" OR "Alveolar Bone Losses" OR "Alveolar Process Atrophy" OR "Alveolar Process Atrophies" OR "Periodontal Bone Losses" OR "Periodontal Bone Loss" OR "Alveolar Bone Atrophy") AND ("Panoramic Radiography" OR "Panoramic Radiographies" OR "panoramic image" OR "panoramic images" OR "panoramic imaging" OR "panoramic radiograph" OR "panoramic radiographs" OR "panoramic X-ray" OR "panoramic" OR "Pantomography" OR "Pantomographies" OR "Orthopantomography" OR "Orthopantomographies") AND ("Cone-Beam" OR "conebeam" OR "CBCT"))

Google Scholar: (("Resorption" OR "Resorptions" OR "alveolar bone loss") AND ("Panoramic Radiography" OR "Panoramic Radiographies" OR "panoramic image" OR "panoramic images") AND ("Cone-Beam" OR "conebeam" OR "CBCT"))

APPENDIX 2

Appendix 2. Excluded articles and reasons for exclusion.

Author, Year	Reason for exclusion
Al-Khateeb, Bataineb, 2006[1]	2
Hermann et al. 2019A[2]	1
Hermann et al. 2019B[3]	1
Jung, Cho, 2015[4]	1
Kim et al. 2017[5]	2
Nemcovisk et al. 1997[6]	3
Yamaoka at al. 1999[7]	2

Legend: 1 - Studies with different objectives (n=3); 2 - Only panoramic radiograph examination (n=3); 3 - Other imaging exams (n=1).

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2.2 Is there a relationship between the presence of external root resorption in second molars adjacent to impacted mandibular third molars with awake bruxism and masticatory muscle activity?

Artigo submetido ao periódico “Clinical Oral Investigations”.

Larissa Moreira-Souza, Elisa Bizetti Pelai, Delaine Rodrigues Bigaton, Deborah Queiroz Freitas, Anne Caroline Costa Oenning, Luciana Asprino

Objectives: To assess whether awake bruxism and masticatory muscle activity may be related to external root resorption (ERR) in second molars adjacent to impacted mandibular third molars.

Materials and Methods: Sixty volunteers, with requests for impacted mandibular third molars evaluation through cone-beam computed tomography (CBCT), were divided into two groups: ERR group, comprising volunteers with ERR in the second molar (n=30), and control group (n=30), according to CBCT assessments. Data regarding awake bruxism were assessed through the Oral Behaviors Checklist (OBC) and an ecological momentary assessment (EMA). Surface electromyography (EMG) was used to assess masseter and anterior temporal muscle function, bilaterally. T-test and Chi-square test were used to compare characteristics between the groups, T-test compared the scores of OBC and EMA and ANOVA compared muscles activity between the groups ($\alpha = 0.05$).

Results: The ERR group presented more non-functional oral activities related to awake bruxism than the control group, according to OBC ($p = 0.027$) and EMA ($p = 0.035$). In addition, the ERR group had higher EMG activity than the control group in rest and isotonic protocols ($p < 0.05$).

Conclusions: Awake bruxism and greater masticatory muscle activity are related to the presence of ERR in second molars adjacent to impacted mandibular third molars.

Clinical Relevance: Identifying factors that increase the chance of third molars triggering ERR in the adjacent teeth can contribute to the early diagnosis and/or the decision to keep or prophylactically remove an impacted mandibular third molar.

Keywords: Bruxism; Cone-Beam Computed Tomography; Electromyography; Masticatory Muscles; Molar, Third; Root Resorption.

Introduction

The dental follicle produces the eruption forces and tooth movements, as it initiates and regulates the required osteoclastogenesis and osteogenesis, in the intraosseous phase of eruption [1]. Studies have shown, through finite element analysis, that the dental follicle of a developing tooth works as a mechanosensor that detects muscle action and, as a result, drives the tooth towards its definitive position in the oral cavity [2,3]. However, in the case of impacted teeth, which is a common problem in dentistry [4], the dental follicle can remain in close contact with the roots of adjacent teeth and the mechanical pressure commonly triggers external root resorption (ERR) [5], a progressive and irreversible pathological process [5], that can be detected by cone-beam computed tomography (CBCT) when it is suspected in two-dimensional radiographies (panoramic or intraoral) [6].

Third molars are the most commonly impacted teeth, with an average worldwide impaction rate of 24%, which occurs mainly in mandibular third molars [7]. Another study, with finite element analysis, showed that regular bite forces simulated by the application of muscular forces, result in high energy dissipation vectors and compression stress in the area of impaction between mandibular third molars and the root of the adjacent second molars [8]. Compression areas have a tissue injury component superimposed on physiological transduction, producing inflammatory products that are primarily resorptive and that stimulate cells to remove the injured tissue [9], triggering, as a result, ERR in the distal root of the second molar.

The bite force is one of the components of chewing function and it is exerted, mainly, by the masseter and temporal muscles [10]. The masseter is a strong and large muscle with a force function that supports bones, protects and drives the power of movement, and elevates the mandible during oral functions; while the temporal muscle is related to speed, being responsible for positioning the mandible [11].

Masticatory muscle tone can be affected by non-functional oral activities [12], which includes abnormal behaviors of the oral structures and associated muscles [13]. Non-functional oral activities, such as bruxism, can increase the thickness of masseter and temporal muscles and, consequently, increase chewing strength [14]. In certain cases, the muscular force during non-functional oral activities can be three times higher than the regular functional activity of the masticatory system [13].

Detecting non-functional oral activities may be challenging because these behaviors are mostly unobservable and unconscious [15]. Wake-time oral behaviors can usually be identified by questionnaires and checklists [15-17] that assess the frequency and level of self-reported oral behaviors [15], such as the Oral Behaviors Checklist (OBC), a self-reported scale for detecting and quantifying the frequency of masticatory muscle overuse based on experiences in the previous month [18]. More objective recordings can be obtained through ecological momentary assessment (EMA) [17] and surface electromyography (EMG) [19]. The EMA is a method that has been used to assess non-functional oral activities, such as awake bruxism, since it quantifies the frequency of the non-functional activities, providing relevant real-time data collection during the day, based on the natural environment of each individual [20]. EMG is a non-invasive tool that captures the number of motor unit action potentials, through surface electrodes [21].

Considering that a mandibular third molar can stimulate sites of compression in adjacent second molars and that the dental follicle works as a mechanosensor that detects muscle action, it could be hypothesized that individuals with non-functional oral activities, such as awake bruxism, and high activity of masticatory muscles, may have a greater chance of developing ERR in second molars compared with individuals with normal activity of these muscles. The lack of pathognomonic symptoms and the difficult access to the impaction area between second and third molars could result in a delayed diagnosis of ERR, which highlights the importance of identifying relevant risk factors [22]. In addition, identifying factors that increase the chances of third molars triggering ERR in the adjacent teeth could contribute to the decision on whether to keep or prophylactically remove an impacted third molar.

Therefore, the present study aimed to assess whether awake bruxism and muscle activity may be related to ERR in second molars adjacent to impacted mandibular third molars. The null hypothesis is that there is no relationship among the factors.

Material and methods

This cross-sectional observational study was approved by the local Ethical Review Board (protocol: #41652015.7.0000.5418) and was conducted following the

Declaration of Helsinki Ethical Principles. All procedures were developed in an oral radiology clinic and a laboratory of a dental school.

Sample selection

Patients who already had a request for a CBCT examination for the preoperative planning of the extraction of retained third molars were selected, between July and December 2019, from the oral radiology clinic of a dental school. The sample included both male and female subjects, aged over 21 years (since third molar root apex closure occurs at around 20 years of age [23]) with all mandibular third molars fully formed, who had at least one second molar adjacent to a horizontally or mesioangular impacted mandibular third molar (risk factor for the development of ERR [8]).

Exclusion criteria comprised patients complaining of pain in teeth or face regions, with a history of trauma or surgery in the maxillofacial structures, those who use medications that could modify the muscle activity (antidepressants, muscle relaxants, anticonvulsants, and non-steroidal anti-inflammatory drugs), with cognitive impairments, with facial deformities and/or significant dental anomalies, with third molars associated with cystic or tumoral lesions, and/or the presence of an extensive carious lesion on the mandibular second molar. The presence of high-density materials (e.g. intracanal post), which can produce beam hardening artifacts, decreasing the CBCT image quality, were also excluded.

The sample size calculation was performed after a pilot study, which used data from eight patients with ERR and eight without ERR. For a power of 95% and an alpha of 5%, a minimum number of 58 patients, 29 per group, was determined. The analysis was performed using GPower software, version 3.1.9.2.

A total of 60 patients (n = 110 impacted mandibular third molars) were recruited for this study and divided into the ERR group (patients with ERR in at least one second molar adjacent to an impacted mandibular third molar; n = 30 patients, n = 45 third molars) and the control group (intact second molar in the region of impaction of the mandibular third molar; n = 30 patients, n = 65 third molars).

Procedures

Each patient was scheduled to perform all procedures on the same day to avoid data and sample loss.

Sample characterization

Sociodemographic data, such as sex, age, body mass (weight), height, and body mass index (BMI), were collected. In addition, the preferred chewing side (PCS) was established by examining the first stroke of the masticatory cycle when chewing a piece of chewing gum. The direction towards which the chewing gum was moved by the tongue on the first cycle of mastication was defined as the preferred side, as proposed by Nissan et al. [24].

CBCT acquisition and evaluation

The images were acquired with the OP300 Maxio unit (Instrumentarium Dental, Tuusula, Finland) adjusted to 90 kVp, 6 mA, an exposure time of 6.1 s, voxel size of 0.2 mm, and field of view of 6 x 8 cm. After the acquisition, the CBCT volumes were exported with the metal artifact reduction algorithm and stored in Digital Imaging and Communications in Medicine (DICOM) format.

The CBCT volumes were evaluated, in consensus, by two oral and maxillofacial radiologists with more than 5 years of experience in CBCT analysis, using OnDemand3D software (Cybermed Inc., Seoul, Republic of Korea) on a 15.6’ Samsung monitor with a 1920×1080-pixel resolution (Samsung Electronics Co., Ltd, Ridgefield Park, NJ, USA). Axial, coronal, and sagittal reconstructions were assessed. Brightness, contrast, and zoom were adjusted freely.

The examiners indicated whether ERR was present or absent on the distal surface of the mandibular second molars, according to the criteria of Al-Khateeb and Bataineh [25], when a clear loss of substance in the root of an adjacent second molar was detected (Figure 1). In addition, the inclination of the mandibular third molar was classified as horizontal or mesioangular, according to Winter’s classification.

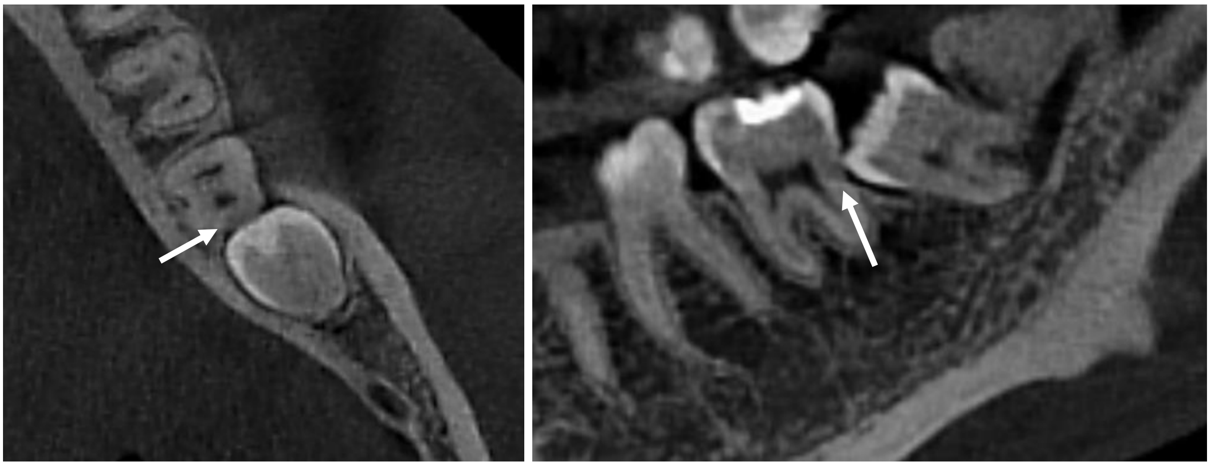

Fig. 1 An impacted left mandibular third molar shown in cone beam computed tomography (CBCT) images. (A) Axial reconstruction. (B) Sagittal reconstruction. Arrows indicate external root resorption detected on the CBCT images.

N*on-functional oral activity assessment*

Non-functional oral activities were obtained by a self-reported questionnaire, the Oral Behaviors Checklist (OBC), and by a smartphone-based ecological momentary assessment (EMA).

The OBC contains 21 items and was used to determine excessive activities of the masticatory muscles in the previous month. Patients were asked to complete questions 3 to 12, which are related to awake bruxism (https://ubwp.buffalo.edu/rdc-tmdinternational/wp-content/uploads/sites/58/2017/01/Oral-Behavior-Checklist_2013-05-12.pdf). The translated and validated version of the OBC was obtained from www.rdc-tmdinternational.org. Each item of the OBC is scored on a scale: none of the time, a little of the time, some of the time, most of the time, and all of the time. The non-functional oral activity was "present" when the frequency on the scale was at least "most of the time", as proposed by Poluha et al. [26]. Each non-functional oral activity present counted as one score. At the end, all scores were summed; the higher the score, the more non-functional oral activities related to awake bruxism reported by the patient.

The EMA quantifies the awake bruxism frequency, providing relevant real-time data collection during the day, based on the natural environment of each individual [20]. For this assessment, patients were previously trained and familiarized with the task. In a pilot test, patients were introduced to a dedicated smartphone application BruxApp® (BruxApp team, Pontedera, Italy). However, due to the difficulty some patients had completing the BruxApp® and because it is not a free app, a researcher was responsible for using it and, for each alert received from the BruxApp®, the same researcher sent a private mobile message to the patients via WhatsApp®, which is a free and widely used instant messaging application. Patients were asked whether they were contracting the masticatory muscles, independently of whether or not they were touching their teeth at that moment (e.g. “do you feel like your masticatory muscles are tense right now?”). The patients were instructed to answer the question with “yes” or “no”.

In the pilot test, approximately 16 alerts were sent per day; however, it was noticed that patient adherence to the EMA was very low. To not lose patients from the sample and focus on patients who contracted the muscles more frequently, one alert was sent in the morning, one in the afternoon, and one in the evening, at random intervals, which could vary from 8h to 12h and from 14h to 22h, on five days of the week, as the response rate is not different on weekdays or weekends [27].

The patient was required to respond to the message within 5 min of the alert. If the patient did not respond, another alert was sent. Additional days were applied until each patient answered 100% of the total alerts (15 alerts).

Muscle activity assessment

For this measurement, the Delsys® electromyograph (Trigno Wireless System®) was used to capture the activation of the anterior temporalis and masseter muscles, bilaterally, following the recommendations of the International Society of Electrophysiology and Kinesiology (ISEK). The collected electromyographic signals were sampled synchronously and stored for later viewing and processing. For the acquisition and storage of data files of the digitized signals, the equipment software (EMGworks®) was used. The analysis was performed in the domain of amplitude to obtain the root mean square values (RMS), expressed in µV.

The EMG was obtained by placing electrodes in the center of the muscle venter, fixed by double-sided adhesive (Figure 2). Before the recordings, the volunteers’ skin was cleaned with 70% alcohol to reduce impedance. Electrode placement was carried out through functional testing of the muscles, which consists of muscle palpation during simultaneous bilateral isotonic contraction [28].

Fig. 2 Positioning of different bipolar electrodes on the masseter and anterior temporal muscles. (A) Lateral view; (B) Anterior view.

The collection was performed in an air-conditioned room, with a controlled temperature maintained at 23º ± 2ºC. To collect the EMG signals, the patients were asked to sit in a chair with their feet flat on the floor, their hands on their lower limbs (knee and hip at 90°), and their gaze parallel to the ground, respecting the Frankfurt plan.

For the rest protocol, the patients were asked to relax for five seconds with their eyes closed [29]. For the isometry collection, the patients were previously familiarized with the task. A Parafilm M®, which is the best palatability material for electromyographic studies and has the smallest coefficient of variation compared to other materials (chewing gum, cotton ball) [30], was positioned bilaterally on the occlusal surfaces of the molars to protect the teeth [30-32]. The patients were required to clench as strongly as possible for 10 s, twice [33]. An interval of one minute between the repetitions was allowed to avoid muscle fatigue.

For the isotonic data collection, patients were trained with respect to chewing rates, using Parafilm M® as mentioned above. Volunteers were instructed to bite the Parafilm M®, and then open the mouth enough to lose tooth contact. The chewing was performed without lip contact. The chewing rhythm was controlled through the use of the digital metronome MA-30 brand KORG (New Market, United States), regulated at 60 beats per minute, under the verbal command of: "bite, bite, bite ..." [34]. Two repetitions of 20 seconds were collected, and the patients performed 20 complete bite/mouth opening cycles (one cycle per second according to the rhythm predetermined by the metronome) [32, 34].

The masticatory cycle was defined as the phases of tooth clenching (contraction of the jaw-lifting muscles, denominated - the 'bite phase' in this study) and the opening of the mouth (contraction of the depressing muscles of the jaw, denominated - the 'mouth opening phase' in this study). The six central masticatory cycles of each collection in the EMG signal were considered to avoid any interference that could have occurred, and to guarantee the standardization of the analyzed signal. For the signal processing, windowing of the bite phase and another of the mouth opening phase of each cycle was used and the mean value of RMS was collected. In this way, the average sum of all RMS values of the six cycles was performed during the bite and opening mouth phases.

EMG data were processed using Matlab® 8.5.0.1976.13 software (R2015a, MathWorks Inc., Natick, Massachusetts, USA). A 4th order digital Butterworth filter with zero phase delay was applied, with a 10 Hz high pass and 400 Hz low pass. The electromyographic signal of the masticatory muscles was normalized, using the RMS value of the bite or mouth opening phase for the second cycle of each collected signal. This form of normalization showed the lowest coefficient of variation compared to other forms of normalization tested in the pilot study.

Statistical analysis

The collected data were tested by the Shapiro-Wilk normality test and the homogeneity of variances was tested by Levene's test, which demonstrated normality and homogeneity of variances.

Descriptive analysis of the sample characterization was performed and expressed in mean and standard deviation. T-test was used to compare variables, as age, weight, height, BMI, and Chi-square test to compare sex and PCS between ERR and control groups. Also, T-test was used to compare the scores of OBC and EMA between groups. For the analysis of variance, ANOVA was used to compare RMS values between both ERR and control groups. Pearson's correlation was performed to measure the statistical relationship between the side with ERR and the PCS. Data processing was performed using SPSS® software, version 17.0 (Chicago, IL, USA). The significance level was set at 5% ($\alpha = 0.05$).

Results

Table 1 summarizes the sample characteristics (age, weight, height, body mass index, sex, and PCS) of all the patients, according to the groups analyzed in the present study. It can be observed that values were similar in all the variables assessed for both groups. In addition, the p-values express the homogeneity of the sample concerning all sample characterization variables. The mean age of the total sample was 24.35 ± 3.74, most of the patients were female (61.66%), and the right side was the most common PCS (73.33%). Considering only the ERR group ($n = 30$), the present study did not find a significant correlation between the PCS and the presence of ERR on the same side ($p = 0.322$).

Table 1. Characterization of the sample according to age, weight, height, and body mass index (BMI), expressed as mean and standard deviation, and sex and preferred chewing side (PCS), expressed as frequency and percentage.

Sample characteristics	**ERR Group (*n*=30)**	**Control Group (*n*=30)**	***p*-value**	**Total Sample (*n*=60)**
Age (years)	25 ± 4.2	23.7 ± 3.1	0.181	24.35 ± 3.74
Weight (kg)	65.03 ± 14.7	66.63 ± 14.29	0.672	65.83 ± 14.4
Height (m)	1.66 ± 0.01	1.68 ± 0.01	0.433	1.67 ± 0.08
BMI (Kg/m2)	23.46 ± 3.85	23.54 ± 3.62	0.823	23.50 ± 3.70
Sex				
Male	9 (30)	13 (43.33)	0.146	23 (38.33)
Female	21 (70)	17 (56.66)		37 (61.66)
PCS				
Right	25 (83.33)	19 (63.33)	0.820	44 (73.33)
Left	5 (16.67)	11 (36.67)		16 (26.67)

ERR: External Root Resorption.

Table 2 shows the OBC and EMA scores for the ERR and control groups. Patients from the ERR group presented more non-functional oral activities related to awake bruxism than the control group, according to the OBC (p = 0.026) and EMA (p = 0.035).

Table 2. Comparison of scores from the Oral Behaviors Checklist (OBC) and Ecological Momentary Assessment (EMA) for non-functional oral activities assessment related to awake bruxism between external root resorption (ERR) and control groups.

	ERR group	**Control group**	***p*-value**
OBC score	91	49	0.027*
EMA score	69	20	0.035*

*p<0.05, according to T-test.

Table 3 presents the comparisons between the RMS values of the masticatory muscles in the ERR and control groups during the chewing cycle. In general, it is possible to observe that the ERR group obtained higher RMS values than the control group, independently of the chewing cycle phase. Significant differences were found mainly for the masseter muscle (p = 0.035, p = 0.49, p = 0.022).

Table 3. Descriptive data of normalized RMS values expressed as mean and standard deviation (SD) of the masticatory muscles (anterior temporalis and masseter, bilaterally) during the chewing cycle for ERR (n=30) and control groups (n=30).

Chewing Cycle	Group	Mean ± SD	*p*-value
Closing phase			
Left Anterior Temporal	ERR	90.48 ± 11.83	0.034*
	Control	84.77 ± 8.11	
Left Masseter	ERR	88.92 ± 14.06	0.035*
	Control	81.38 ± 13.03	
Right Anterior Temporal	ERR	90.65 ± 13.15	0.072
	Control	85.12 ± 10.06	
Right Masseter	ERR	89.59 ± 14.75	0.076
	Control	83.17 ± 12.63	
Opening phase			
Left Anterior Temporal	ERR	100.75 ± 42.43	0.109
	Control	86.93 ± 19.16	
Left Masseter	ERR	100.63 ± 35.83	0.049*
	Control	83.46 ± 30.65	
Right Anterior Temporal	ERR	96.92 ± 43.39	0.113
	Control	83.39 ± 15.46	
Right Masseter	ERR	99.72 ± 38.94	0.022*
	Control	80.27 ± 22.53	

RMS: Root Mean Square, ERR: External Root Resorption.

*p<0.05, according to ANOVA test.

Table 4 presents the comparisons between the RMS values of the masticatory muscles in the ERR and control groups during the rest and isometry protocols, with significant differences between the groups, mainly for the rest protocol (p < 0.05 for all masticatory muscles assessed). In contrast, no significant differences were found between the ERR and control groups in the isometry protocol, except for the right masseter muscle (p = 0.049), which presented higher RMS values for the control group.

Table 4. Descriptive data of normalized RMS values expressed as mean and standard deviation (SD) of the masticatory muscles (anterior temporal and masseter, bilaterally) during rest and isometry protocols for ERR (n=30) and control groups (n=30).

PROTOCOLS	MUSCLE	GROUP	MEAN ± SD	p-value
REST	Left Anterior Temporal	ERR	7.45 ± 4.47	0.000*
		Control	2.67 ± 1.18	
	Left Masseter	ERR	2.84 ± 1.61	0.024*
		Control	2.01 ± 1.11	
	Right Anterior Temporal	ERR	7.30 ± 5.65	0.000*
		Control	2.72 ± 1.62	
	Right Masseter	ERR	3.74 ± 2.87	0.003*
		Control	1.97 ± 0.77	
ISOMETRY	Left Anterior Temporal	ERR	110.99 ± 48.15	0.101
		Control	145.42 ± 101.45	
	Left Masseter	ERR	170.04 ± 165.25	0.110
		Control	229.17 ± 110.79	
	Right Anterior Temporal	ERR	119.84 ± 68.00	0.099
		Control	177.14 ± 120.37	
	Right Masseter	ERR	179.97 ± 131.76	0.049*
		Control	245.64 ± 120.68	

RMS: Root Mean Square, ERR: External Root Resorption.

*p<0.05, according to ANOVA test.

Discussion

To the best of our knowledge, this is the first study in the literature to assess whether awake bruxism and masticatory muscle activity have a relationship with ERR in second molars adjacent to impacted mandibular third molars. In the present study, patients from the ERR group presented more non-functional oral activities related to the awake bruxism than the control group. Furthermore, the ERR group presented higher EMG activity of the masticatory muscles than the control group for the rest and isotonic protocols, which could explain part of the relationship with the development of ERR in mandibular second molars.

Eruptive forces permit a tooth to emerge from its beginning position inside the jaw to occlude with its antagonist in the oral cavity [35, 36]. Studies published by Sarrafpour et al. [2, 3] suggested, using finite element analysis, that these forces are not genetically programmed, but stimulated by local factors related to the orofacial musculature. However, impacted teeth find a physical barrier in their eruption path that restricts their normal eruptive course, and the eruptive forces are transmitted to the site of impaction [8]. In addition, Oenning et al. suggested, also using finite element analysis, that impacted third molars in contact with second molars may generate areas of compression at the site of contact, which suggests an involvement of mechanical factors in the triggering of ERR.

Considering that awake bruxism is a masticatory muscle activity during wakefulness, described as a motor behavior with repetitive or constant tooth contact and/or forcefully maintaining a certain mandibular position, without the needed for the presence of tooth contact [37], and that non-functional oral activities related to bruxism share a common characteristic connected to the overuse of the masticatory muscles [38], it was hypothesized that greater use and high activity of masticatory muscles could be risk factors for the development of ERR in second molars adjacent to impacted third molars.

As a gold standard for the evaluation of muscle activity, EMG was used in the present study. The main clinical application of EMG in dentistry is to register the electrical potential of the masticatory muscles. Although masticatory muscles include the masseter, temporal, medial, and lateral pterygoid muscles, in the present study, the superficial masseter and anterior temporal muscles were evaluated through EMG because these superficial muscles are primary targets to study, being easily accessible muscles that act directly on the function of the stomatognathic system and orofacial structures [39].

Fibers from the superficial part of the masseter muscle insert onto the angle of the mandible at the masseteric tubercle, as well as onto the inferior portion of the lateral surface of the mandibular ramus [40], which is close to the development site of the mandibular third molar. However, the deep part of the masseter muscle, even closer to the mandibular third molar, is situated at a deeper level than the superficial masseter. The deep part inserts on the mandibular ramus, superior and deep to the superficial portion [41]. Consequently, it is possible that not all muscle fibers are considered in the surface EMG and the deep part of the masseter muscle, closer to the mandibular third molar, remains undetected [42]. For this reason, the anterior temporal muscle was also considered in this study, as some temporal muscle fibers insert adjacent to a third molar, reaching the medial surface of the mandibular ramus [43]. Even so, significant differences were found in masseter muscle activity, both in the rest and isotonic protocols, which can be explained by the fact that the masseter muscle is the most prominent masticatory muscle, being responsible for elevating the mandible and exerting masticatory force [41].

It is important to highlight that, in the present study, the EMG signal of the masticatory muscles was normalized, because intrinsic and extrinsic factors can impact the collection of the EMG signal (adipose tissue, skin temperature, electrode configuration, electrode positioning, and inter-electrode distance) [21]. These factors can impair the comparison of the signal between different groups of individuals and/or between different muscle groups [21, 44]. Therefore, it is recommended that the amplitude of the EMG signal should be normalized so that the EMG can be safely used for comparison between groups, muscles, and/or days.

Comparing the masticatory muscle activity between the ERR and control groups, the ERR group presented higher EMG activity (RMS values) than the control group, mainly for the masseter muscle, in the rest and isotonic protocols. Recording the EMG activity of the temporal and masseter muscles with the mandible at rest is as fundamental as the evaluation in isometry and isotonic because it allows comparisons between individuals, since the rest is maintained even with the tonicity of the muscles that counterbalance the action of gravity. and negative intraoral pressure [45].

There is still insufficient evidence to support or refute routine prophylactic removal of asymptomatic impacted third molars in adults [46]. However, in general, the present study found more awake bruxism and higher masticatory muscle activity in patients with ERR. The presence of these conditions should be taken into consideration for suspected ERR in patients with a mesioangular or horizontal impacted mandibular third molar, which are already risk factors for the development of ERR, probably because of a relatively large contact area between the third molar and the second molar [8, 22]. Surgeons could take this into account as factors that can help diagnose ERR in its early stages and can suggest further investigation through panoramic radiography and, if necessary, CBCT, to better evaluate the presence and extension of ERR [6]. In early stages of ERR, it is possible to consider the treatment for awake bruxism as an approach to prevent the progression of the resorption.

For several human activities, there is a lateral preference, which is a tendency to use one side of the body (for example, the majority of subjects prefer either the right or left hand). Most experts agree that mastication is no exception and there is also a preference side [47]. The present study showed a preference towards the right side for both groups, which is in line with studies suggesting that more adults prefer the right side [48, 49].

Although there was no significant correlation between the side of the mandible with ERR and the PCS, if we consider only patients with unilateral ERR, 12 patients had ERR on the same side as the PCS; while only 6 patients presented ERR on the opposite side to the PCS. Thus, there seems to be a tendency for the PCS and ERR to be related, possibly because on the PCS, the major frequency of bite force can stimulate energy dissipation in the contact area between the impacted third molar and the second molar. The sample size of the ERR group (n = 30) may have been the reason why a significant correlation was not found. Thus, the present authors suggest a deeper investigation into the development of ERR on the PCS, involving a larger sample of patients with ERR.

One of the limitations of this study is the lack of measurement of bite force. During the isometry protocol, the patients were stimulated to set their maximum amplitude of contraction by a verbal command provided by the researcher of “maximum force, maximum force, maximum force, …”. As there was no monitoring, the bite force could not be stated. However, the presence of non-functional oral activities was assessed. The bite force during non-functional oral activities can be three times higher than the regular functional activity of the masticatory system [13]. Future studies should further investigate the relationship between excessive bite forces, measured with a gnathodynamometer and the presence of ERR.

The lack of pathognomonic symptoms emphasizes the importance of recognizing the risk factors for ERR. The results of the present study can reinforce the theory that triggering ERR in the second molars adjacent to impacted mandibular third molars may be related to mechanical forces coming from the masticatory function.

CONCLUSION

Patients with more non-functional oral activities related to awake bruxism and higher masticatory muscles activity demonstrated a relation with the development of ERR in second molars adjacent to impacted mesioangular or horizontal mandibular third molars.

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3 DISCUSSÃO

Terceiros molares impactados podem provocar condições patológicas, como reabsorção radicular externa (RRE) e perda óssea localizada (POL) em segundos molares adjacentes (Herman et al., 2019). Tais condições podem evoluir sem sintomatologia (Matzen et al., 2016; Kim 2017), resultando em um diagnóstico tardio, o que destaca a importância da identificação dos seus fatores de risco (Li et al., 2019) e a indicação correta de exames complementares (como exames de imagem).

Através de uma revisão sistemática da literatura, a presente tese mostrou que a prevalência de RRE em segundos molares adjacentes a um terceiro molar impactado foi de 5,3% a 19,5% em radiografias panorâmicas, enquanto em imagens de TCFC, a sua prevalência foi de 22,8% a 62% (Oenning et al., 2014; D'Costa et al., 2017; Matzen et al., 2017). Já com relação à POL, sua prevalência, em radiografias panorâmicas, foi de 21,9% a 62,9%, enquanto em exames de TCFC, essa prevalência foi de 21,6% a 80% (Matzen et al., 2017; Dias et al., 2020).

O aumento na detecção de RRE nos exames de TCFC já foi discutido anteriormente (Matzen et al., 2017), indicando que a análise tridimensional de um objeto, sem aumento ou distorção na imagem e sem sobreposição das estruturas adjacentes, desempenha um papel significativo nessa maior detecção (Oenning et al., 2014; Matzen et al., 2017). Ao contrário, a avaliação em radiografias panorâmicas restringe-se a dois planos e está sujeita a ampliação, distorção e projeção da imagem do terceiro sobre o segundo molar, dificultando a detecção das alterações no contorno da superfície radicular dos segundos molares (Oenning et al., 2014).

Em contraste com a RRE, onde a diferença na prevalência encontrada em radiografias panorâmicas e TCFC foi claramente maior, para a POL, essa diferença não foi tão discrepante. As vantagens do exame de imagem tridimensional comparada ao exame de imagem bidimensional, no entanto, também se aplicam para a maior detecção de POL nas imagens TCFC (Matzen et al., 2017; Dias et al., 2020), uma vez que na imagem de radiografia panorâmica, a sobreposição das corticais vestibular e lingual pode mascarar a perda óssea.

Uma revisão sistemática publicada anteriormente indica a TCFC como um método confiável para a detecção de RRE, embora os estudos incluídos tenham avaliado apenas lesões de RRE simuladas *in vitro* (Yi et al., 2017). Porém, ressalta-se que, clinicamente, a TCFC pode não ser tão precisa na detecção de RRE, quanto estudos *in vitro* afirmaram anteriormente (Deliga Schröder et al.,2019). Além disso, o exame de TCFC, nos casos em que houver suspeita de RRE na radiografia panorâmica, pode alterar o planejamento do tratamento (Hermann et al., 2019). Para avaliação da POL, a TCFC é um método bem estabelecido (Walter et al., 2020).

Além da prevalência da RRE e da POL em segundos molares adjacentes à terceiros molares impactados, a presente revisão sistemática também verificou a concordância entre radiografia panorâmica e TCFC em relação à detecção destas condições. A concordância entre essas modalidades de exames de imagem para RRE foi de 28,5% a 80,3% (Oenning et al., 2014; D'costa et al., 2017; Matzen et al., 2017; Mendonça et al., 2020), enquanto para POL foi de 66% a 85% (Matzen et al., 2017; Mendonça et al., 2020). Em geral, a concordância entre radiografia panorâmica e TCFC mostra uma porcentagem ligeiramente maior para POL. Conforme Dias et al. (2020), essa concordância maior para POL não poderia ser a mesma ao lidar com tarefas diagnósticas mais minuciosas, como a RRE.

Embora os estudos tenham mostrado uma concordância relativamente alta entre radiografia panorâmica e TCFC para detecção de RRE, isso está principalmente relacionado a concordância quanto a ausência da condição. No estudo de Oenning et al. (2014), a concordância quanto a presença de RRE foi de 4,3%, enquanto para a ausência foi de 76%. Matzen et al. (2017) encontraram uma concordância para presença de POL de 24%, enquanto para a sua ausência, a concordância foi de 51,6%. Por outro lado, Dias et al. (2020) encontraram maior concordância para a presença de POL (58,9%) em comparação com a sua ausência (15,3%). Esses resultados controversos entre esses estudos podem estar relacionados às questões metodológicas relacionadas à avaliação das imagens. Enquanto um estudo contou com quatro radiologistas orais para avaliar as imagens de forma independente (Matzen et al., 2017), o último contou com dois radiologistas orais, que avaliaram as imagens em consenso (Dias et al., 2020).

Os estudos incluídos nesta revisão sistemática também revelaram resultados adicionais. Lesões de RRE, geralmente, estão localizadas na porção cervical da raiz dos segundos molares (D'Costa, 2017). Terceiros molares inferiores em inclinações mesioangular e horizontal são fatores de risco para o desenvolvimento de RRE e

POL (Oenning et al., 2014; Dias et al., 2020; Matzen et al.,2017). Além disso, a radiografia panorâmica tende a subestimar o grau de severidade da POL, em comparação com a avaliação em TCFC (Dias et al., 2020) e a frequência de decisão de remoção dos terceiros molares são aumentadas quando as avaliações são feitas em imagens de TCFC (Matzen et al., 2017), embora a mudança de diagnóstico de ausência de RRE em radiografia panorâmica para presença de RRE em TCFC não seja capaz de alterar o planejamento cirúrgico (Mendonça et al., 2020).

Identificar os fatores de risco relacionados à RRE é importante, uma vez que a falta de sintomas patognomônicos e seu difícil acesso pode resultar em um diagnóstico tardio (Li et al., 2019). Portanto, também foi um dos objetivos desta tese, avaliar se atividades orais não funcionais, como o bruxismo de vigília, e a atividade dos músculos da mastigação têm relação com o surgimento de RRE em segundos molares adjacentes a terceiros molares inferiores impactados. No presente estudo, os pacientes do grupo RRE apresentaram mais atividades orais não funcionais relacionadas ao bruxismo de vigília, comparado ao grupo controle. Além disso, o grupo RRE também apresentou maior atividade dos músculos, o que poderia explicar parte da relação entre os músculos mastigatórios e o desenvolvimento de RRE em segundos molares inferiores.

As forças eruptivas permitem que um dente emerja de sua posição inicial dentro da mandíbula para ocluir com o dente antagônico na cavidade oral (Proffit et al., 1978; Steedle et al., 1978). Estudos publicados por Sarrafpour et al. (2012, 2013) sugeriram, através da análise de elementos finitos, que essas forças não são geneticamente programadas, mas estimuladas por fatores locais relacionados à musculatura orofacial. No entanto, os dentes impactados encontram uma barreira física em seu trajeto de erupção que restringe seu curso eruptivo normal e as forças eruptivas são transmitidas ao local da impactação (Oenning et al., 2018).

Os movimentos dentários eruptivos não cessam com a conclusão da formação da raiz e fechamento do seu ápice, o que implica que um dente impactado continua a exercer pressão sobre o dente adjacente (Sarrafpour et al., 2013). Essa pressão mecânica, por sua vez, pode estar associada ao recrutamento de células clásticas, o que resultaria na reabsorção de cemento e dentina, causando RRE (Fuss et al., 2003). Os autores do presente estudo selecionaram pacientes com pelo menos 21 anos de idade, uma vez que o fechamento do ápice radicular dos terceiros molares ocorre por volta dos 20 anos de idade (Kullman et al., 1992). Assim, a pressão mecânica nos segundos molares causada pela formação das raízes do terceiro molar impactado foi isolada, permitindo a avaliação da pressão mecânica a partir de outros fatores, como a influência da musculatura orofacial (Sarrafpour et al., 2013; Oenning et al., 2018).

De acordo com alguns estudos que avaliaram a prevalência de RRE em segundos molares, terceiros molares inferiores mesioangulares e horizontais são fatores de risco para o desenvolvimento de RRE, provavelmente devido a uma área de contato relativamente grande entre o terceiro molar e o segundo molar (Oenning et al., 2018; Li et al., 2019). Por esses motivos, os presentes autores selecionaram pacientes com terceiros molares impactados nessas angulações.

Dos pacientes incluídos no grupo RRE, 70% eram do sexo feminino. Parece não haver explicação óbvia para esse achado, exceto que as mulheres procuram mais cuidados de saúde do que os homens. É importante destacar que a distribuição entre os sexos não diferiu tanto no grupo RRE quanto no controle (p=0,146). Enquanto outros estudos não encontraram associação entre sexo e RRE (Wang et al., 2017; Oenning et al., 2015; Li et al., 2019), alguns autores relataram maior risco em pacientes do sexo masculino (Nitzan et al., 1981; Suter et al., 2019), e outros em pacientes do sexo feminino (Tunç et al., 2020), propondo que os hormônios sexuais poderiam ser um dos fatores sistêmicos envolvidos no processo de RRE.

Em relação à idade dos pacientes, o grupo RRE apresentou média de idade de 25 anos. Li et al. (2019) e Tunç et al. (2020) não encontraram associação significativa entre prevalência de RRE em segundos molares inferiores e idade, provavelmente porque um terceiro molar inferior é mais facilmente sintomático ou mais visualmente acessível, levando a uma extração mais precoce. No entanto, uma vez que o RRE ocorre, sua gravidade aumenta com a idade porque a reabsorção radicular induzida pela pressão mecânica dos dentes impactados é progressiva ao longo do tempo (Wang et al., 2017). Os presentes resultados acrescentam novas informações a esta afirmação: além da progressão contínua da RRE após o fechamento do ápice, comportamentos, como o bruxismo de vigília, e maior atividade dos músculos mastigatórios podem aumentar a gravidade da condição.

Para várias atividades humanas, há uma preferência lateral, que é uma tendência de usar um lado do corpo (por exemplo, a maioria dos sujeitos prefere a mão direita ou esquerda). A maioria dos especialistas concorda que a mastigação não é exceção, e que também existe um lado de preferência mastigatória (Varela et al., 2003). O presente estudo mostrou preferência pelo lado direito para ambos os grupos, o que está de acordo com estudos que sugeriram que mais adultos preferem o lado direito (Martinez-Gomis et al., 2009; Zamanlu et al., 2012). Considerando apenas o grupo RRE (n = 30) e apenas a presença de RRE unilaterais, 12 pacientes que apresentaram RRE e preferência mastigatória no mesmo lado, enquanto apenas 6 pacientes apresentaram RRE no lado oposto ao lado de preferência mastigatória. Se levarmos esses dados em consideração, parece haver uma tendência entre o lado de preferência mastigatória e o lado com RRE, possivelmente porque no lado mastigatório preferido, a frequência de força de mordida aplicada e a atividade muscular são maiores, estimulando a dissipação de energia na área de contato entre o terceiro molar impactado e o segundo molar (Oenning et al., 2018).

Embora os músculos mastigatórios incluam os músculos masseter, temporal, medial e pterigóideo lateral, no presente estudo, os músculos masseter e a porção anterior do músculo temporal foram avaliados por meio da eletromiografia de superfície (EMGs), pois esses músculos são mais superficiais, sendo de fácil acesso e que atuam diretamente sobre a função do sistema estomatognático e estruturas orofaciais (Ferreira et al., 2017).

Comparando a atividade de tais músculos entre o grupo RRE e controle, o grupo RRE apresentou maior atividade muscular que o grupo controle, principalmente para o músculo masseter, nos protocolos de repouso e isotônia. Registrar a atividade EMG dos músculos temporal e masseter com a mandíbula em repouso é tão fundamental quanto a avaliação em isometria e isotonia, porque permite comparações entre indivíduos, uma vez que o repouso é mantido ainda com a tonicidade dos músculos que contrabalançam a ação da gravidade e a pressão intra-oral negativa (Sgobbi de Faria; Bérzin, 1998).

Além disso, os pacientes do grupo RRE apresentaram mais comportamentos relacionados ao bruxismo de vigília do que o grupo controle. Esses comportamentos orais compartilham de uma característica comum relacionada ao uso excessivo dos músculos da mastigação (Ohrbach et al., 2008). Com base na análise de elementos finitos, Oenning et al. (2018) mostraram que as forças de mordida normais simuladas resultaram em áreas de alta dissipação de energia e tensão de compressão do terceiro molar inferior na raiz do segundo molar adjacente. Diante disso e, considerando que a força de mordida durante atividades orais não funcionais pode ser três vezes maior do que a atividade funcional regular do sistema mastigatório (Demjaha et al., 2019), indivíduos com atividades orais não funcionais podem ter maior chance de estimular a dissipação de energia e o estresse por compressão na área de impactação do segundo e terceiro molares inferiores, causando RRE nos segundos molares.

Ainda não há evidências suficientes para apoiar ou refutar a remoção profilática de rotina de terceiros molares impactados assintomáticos em adultos (Ghaeminia et al., 2016). No entanto, o presente estudo encontrou maior frequência de RRE em pacientes com alta atividade muscular e bruxismo de vigília. Além disso, a presença dessas condições deve ser levada em consideração para suspeita de RRE em pacientes com terceiro molar inferior impactado mesioangular ou horizontal. Tais fatores podem ajudar a diagnosticar a RRE em seus estágios iniciais e sugerir investigação adicional por meio de radiografia panorâmica e, se necessário, TCFC para melhor avaliar a presença e extensão da RRE (Moreira-Souza et al., 2021). Além disso, a identificação dessas condições em pacientes com terceiros molares inferiores, impactados e em posição mesioangular ou horizontal podem sugerir o tratamento do bruxismo de vigília como uma prevenção para o surgimento de RRE nos segundos molares adjacentes, além de indicar procedimento de exodontia ou coronectomia do terceiro molar para eliminar o estímulo à RRE. A ausência de sintomas patognomônicos enfatiza a importância de reconhecer fatores de risco para o desenvolvimento ou gravidade da RRE. Portanto, estudos futuros podem investigar mais profundamente a relação entre forças de mordida excessivas (com mensurações objetivas) e a presença de RRE e se o lado de preferência mastigatória e o lado do segundo molar inferior com RRE estão relacionados e não são apenas uma tendência, como mostrado neste estudo. Um estudo futuro envolvendo apenas pacientes com RRE e com um tamanho amostral mais adequado para aplicação de testes estatísticos apenas neste grupo pode levar a uma melhor avaliação desta relação. Ainda, levando em consideração que os autores do presente estudo avaliaram apenas segundos e terceiros molares inferiores, seria interessante um estudo que considerasse também os molares superiores.

4 CONCLUSÕES

Parece razoável afirmar que o exame bidimensional é sempre a primeira escolha para avaliar terceiros molares. No entanto, a TCFC pode ser indicada se houver suspeita de RRE no dente adjacente, pois há um aumento significativo na detecção dessa condição no exame de TCFC.

Em relação à POL, embora a TCFC também proporcione maior detecção que a radiografia panorâmica, esta diferença não é muito expressiva. Portanto, parece razoável recomendar que, após a radiografia panorâmica, se houver suspeita de RRE em um segundo molar adjacente a um terceiro molar mesioangular ou horizontal, recomenda-se a TCFC para melhor avaliação.

Os resultados da presente tese também podem reforçar a hipótese (teoria) de que o desencadeamento do RRE nos segundos molares adjacentes à terceiros molares inferiores impactados pode estar relacionado a forças mecânicas advindas da função mastigatória. Pacientes que possuem bruxismo de vigília, além de maior atividade dos músculos da mastigação, parecem ter mais chance de desenvolver RRE em segundos molares adjacentes a terceiros molares inferiores impactados.

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APÊNDICE 1

METODOLOGIA DETALHADA

Artigo 1 - Comparison of panoramic radiography and CBCT for the assessment of external root resorption and marginal bone loss of second molar associated with third molar impaction: a systematic review.

O protocolo desta revisão sistemática foi desenvolvido, seguindo recomendações do PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) e o protocolo do estudo foi registrado no PROSPERO (Prospective Register of Systematic Reviews), disponível sob o número de registro CRD42020136588 (Anexo 1). Ainda, a presente revisão sistemática cumpriu os requisitos da lista de verificação do PRISMA e do SWiM (Synthesis Without Meta-analysis).

A questão levantada para a realização desta revisão foi: “O uso de TCFC é determinante para a avaliação de ERR ou MBL envolvendo um segundo molar adjacente a um terceiro molar impactado?”. Assim, essa mesma pergunta foi utilizada para estabelecer uma estratégia de busca apropriada para cada um dos seguintes bancos de dados eletrônicos com o apoio de um bibliotecário de ciências da saúde: PubMed, EMBASE, Scopus, Web of Science and Latin American and Caribbean Health Sciences (LILACS), Google Scholar, OpenGrey e ProQuest Dissertations & Theses Global. As estratégias de busca utilizadas para cada base de dados mencionada anteriormente se encontram no anexo 2 desta tese.

Todas as referências foram gerenciadas pelo software Mendeley (Mendeley Ltd., Londres, Reino Unido) e os artigos duplicados foram removidos. Não houve restrições quanto ao idioma ou período de publicação.

Critérios de elegibilidade

Foram incluídos estudos que avaliaram a detecção e a prevalência de reabsorção radicular externa (RRE) ou perda óssea localizada (POL) em segundos molares adjacentes à terceiros molares impactados, por meio de radiografias panorâmicas (PAN) e tomografia computadorizada de feixe cônico (TCFC). Foram excluídos relatos de casos, revisões, cartas e opiniões pessoais.

Seleção de estudos e coleta de dados

Foram encontrados 593 artigos após a aplicação das estratégias de busca, restando 586 após a aplicação da ferramenta para remoção de artigos duplicados. Para a seleção dos artigos, foi adotado um processo em duas fases. Primeiramente, dois revisores (L.M.S. e M.A.M.) leram os títulos e resumos dos artigos encontrados de acordo com as estratégias de busca. Assim, 22 artigos (estudos de prevalência e de testes de diagnóstico) passaram para segunda fase do processo de seleção e foram lidos em sua totalidade, sendo o restante excluídos por serem revisões, relatos de casos, cartas, opiniões pessoais e por terem avaliado dentes diferentes dos segundos e terceiros molares). Doze artigos preencheram os critérios de inclusão, porém 7 deles foram excluídos por outras razões (avaliaram RRE e/ou POL apenas em PAN ou apenas em TCFC ou utilizaram outros métodos de exames de imagem). Ao final, 5 artigos foram selecionados para a presente revisão sistemática. Os dois revisores (L.M.S. e M.A.M.) realizaram a seleção dos estudos e a coleta de dados de forma independente. Um terceiro (A.C.O.) e um quarto revisor (L.B.O) foram consultados em caso de discordância entre o primeiro e o segundo revisor.

Para extração de dados, inicialmente, dois revisores (L.M.S e M.A.M) coletaram os dados de forma independente e os compararam posteriormente. Um terceiro revisor, um radiologista experiente, verificou os dados coletados (A.C.O.).

As seguintes informações foram coletadas: autor, ano, país, tamanho da amostra, desfechos, parâmetros associados, parâmetros de aquisição de imagem, análise estatística, prevalência de RRE e POL e concordância entre PAN e TCFC, outros achados e principais conclusões dos autores.

Análise de risco de viés em cada artigo selecionado

A qualidade metodológica dos estudos incluídos foi avaliada usando a ferramenta de risco de viés MAStARI (Meta-Analysis of Statistical Assessment and Review Instrument) (Anexo 2). A avaliação dos artigos foi realizada por três revisores

(L.M.S, H.G.A e A.C.O). Os artigos foram classificados de acordo com a proporção de “sim” que receberam em cada item do MAStARI: risco de viés alto (até 49% pontuação “sim”), moderado (50-69% pontuação “sim”) e baixo (>70% pontuação “sim”) (Anexo 3). Além disso, a ferramenta online *robvis* (Visualização de risco de viés) foi usada para gerar as figuras do presente estudo.

Síntese dos resultados

A heterogeneidade dos estudos foi avaliada com base nas suas características, características das metodologias e dos resultados. Todos os estudos incluídos apresentaram os dados coletados; no entanto, não foi realizada uma meta-análise devido às disparidades metodológicas.

Artigo 2 – Is there a relationship between the presence of external root resorption in second molars adjacent to impacted lower third molars and the presence of awake bruxism and masticatory muscles activity?

Este estudo observacional transversal foi aprovado pelo Comitê de Ética em Pesquisa local (protocolo: #41652015.7.0000.5418) e foi conduzido de acordo com a Declaração dos Princípios Éticos de Helsinki. Os pacientes que concordaram em participar desta pesquisa assinaram um termo de consentimento livre e esclarecido e todos os procedimentos foram desenvolvidos na clínica de radiologia odontológica da Faculdade de Odontologia de Piracicaba (FOP-UNICAMP) e no laboratório da área cirurgia buco-maxilo-facial da mesma faculdade.

Seleção de amostra

Foram selecionados pacientes, entre Julho e Dezembro de 2019, da clínica de radiologia odontológica da FOP-UNICAMP, que já possuíam solicitação de exame de tomografia computadorizada de feixe cônico (TCFC) para o planejamento pré-operatório de exodontia de terceiros molares inferiores, devido à relação de proximidade com o canal mandibular.

A amostra incluiu indivíduos do sexo masculino e feminino, com idade superior a 21 anos, uma vez que o fechamento do ápice radicular dos terceiros molares ocorre por volta dos 20 anos de idade (Kullman, 1992). Assim, a pressão mecânica nos segundos molares causada pela formação das raízes do terceiro molar impactado poderia ser isolada, permitindo a avaliação da pressão mecânica a partir de outros fatores. Ainda, foram incluídos pacientes que apresentavam pelo menos um segundo molar adjacente a um terceiro molar inferior impactado e em posição mesioangular ou horizontal. Todos os terceiros molares inferiores tinham que estar com as raízes totalmente formadas e ápices radiculares fechados.

Pacientes com queixa de dor em qualquer dente ou região da face, com histórico de trauma ou cirurgia nas estruturas maxilo-faciais, que faziam uso de medicamentos que poderiam mascarar sintomas de hiperatividade muscular (antidepressivos, relaxantes musculares, anticonvulsivantes e anti-inflamatórios não esteroides), com deficiências cognitivas, com deformidades faciais e/ou anomalias dentárias significativas, com terceiros molares associados a lesões císticas ou tumorais e/ou presença de lesão cariosa extensa no segundo molar inferior foram excluídos da amostra. Além disso, a presença de materiais de alta densidade (como retentor intra-radicular) podia produzir artefatos de endurecimento do feixe, diminuindo a qualidade da imagem de TCFC. Nesse caso, se esses artefatos impossibilitassem a avaliação da área de interesse, o exame era excluído.

O cálculo do tamanho da amostra foi realizado com dados de 8 pacientes com a condição estudada e 8 sem a condição. Com um poder de 95% e um alfa de 5%, foi determinado um número total de 58 pacientes, 29 por grupo. A análise foi realizada com o software GPower, versão 3.1.9.2.

Sequência dos procedimentos

Cada paciente foi agendado para realizar todos os procedimentos no mesmo dia para evitar perda de dados e pacientes da amostra.

Caracterização da amostra

Foram coletados dados sociodemográficos, como sexo, idade, massa corporal (peso), estatura e índice de massa corporal (IMC). Além disso, o lado de preferência mastigatória foi estabelecido examinando a direção em que uma goma de mascar foi movida pela língua no primeiro ciclo de mastigação, conforme proposto por Nissan et al. (2011).

Aquisição de exames de imagem

As imagens foram adquiridas no aparelho OP300 Maxio (Instrumentarium Dental, Tuusula, Finlândia), utilizando os seguintes parâmetros energéticos: 90 kVp, 6 mA, tempo de exposição de 6.1 s, tamanho de voxel de 0,2 mm e utilizando um campo de visão de 6 x 8 cm. Após a aquisição das imagens, os volumes foram exportados com o algoritmo de redução de artefatos e armazenados no formato Digital Imaging and Communications in Medicine (DICOM).

Os exames de TCFC foram avaliados, em consenso, por dois radiologistas orais, com mais de 5 anos de experiência em avaliação de imagens de TCFC em um monitor Samsung de 15,6’ com resolução de 1920 × 1080 pixels (Samsung Electronics Co., Ltd, Ridgefield Park, NJ, EUA), utilizando o software Ondemand 3D (Cybermed Inc., Seoul, Republic of Korea). As reconstruções axial, coronal e sagital foram avaliadas e os examinadores utilizaram as ferramentas de ajuste de brilho, contraste e zoom, conforme necessidade.

Os avaliadores classificavam a presença de RRE através de escores, sendo eles: 0 - para ausência de RRE; 1 - para presença da RRE na superfície distal dos segundos molares inferiores, de acordo com os critérios de Al-Khateeb e Bataineh (2006), quando era detectada uma clara perda de substância na raiz distal de um segundo molar adjacente a um terceiro molar impactado. Além disso, a inclinação do terceiro molar inferior foi determinada usando a classificação de Winter (1926) em horizontal ou mesioangular. De acordo com Winter (1926), os terceiros molares podem ser classificados conforme a inclinação do seu longo eixo em relação ao longo eixo do segundo molar. Quando a coroa do terceiro molar se encontrava mais próxima à raiz do segundo molar, sua inclinação era classificada como mesioangular. Caso esta angulação fosse tão acentuada que o longo eixo do terceiro molar estava perpendicular ao longo eixo do segundo molar, classificou-se como uma angulação horizontal.

Conforme as avaliações dos exames de TCFC, os pacientes foram divididos em dois grupos: grupo RRE (pacientes com RRE em pelo menos um segundo molar adjacente a um terceiro molar inferior impactado) e grupo controle (segundo molar íntegro na região de impactação com terceiro molar inferior).

Avaliação das atividades orais não funcionais

A presença de atividades orais não funcionais foi investigada por meio de um questionário autorreferido denominado OBC (*oral behaviors checklist*) e por uma avaliação realizada através de um *smartphone* chamada EMA (*ecological momentary assessment*).

O OBC é uma escala de autorrelato para detectar e quantificar a frequência de comportamentos de uso excessivo da mandíbula com base em experiências no mês anterior (Anexo 4). O OBC contêm 21 itens, selecionados para determinar atividades excessivas dos músculos mastigatórios. Os pacientes foram solicitados a preencher as questões de 3 a 12, que estão relacionadas ao bruxismo de vigília (https://ubwp.buffalo.edu/rdc-tmdinternational/wp-content/uploads/sites/58/2017/01/Oral-Behavior -Checklist_2013-05-12.pdf). A versão em português do OBC foi obtida em www.rdc-tmdinternational.org.

Cada item do OBC é pontuado em uma escala que vai de “nenhuma das vezes”, “raramente”, “às vezes”, “frequentemente” a “sempre”. Uma atividade oral não funcional foi considerada como “presente” quando a frequência marcada na escala era “frequentemente” ou “sempre” conforme proposto por Poluha et al. (2021). Cada atividade oral não funcional presente contava como uma pontuação. Ao final, as pontuações do OBC eram somadas; quanto maior a pontuação, mais atividades orais não funcionais relacionadas ao bruxismo de vigília o paciente relatou.

O EMA é um método que vem sendo utilizado para avaliar a frequência de atividades orais não funcionais, como o bruxismo de vigília, fornecendo dados relevantes em tempo real durante o dia, com base no ambiente natural de cada indivíduo (Câmara-Souza et al., 2020). Para esta avaliação, os pacientes foram previamente familiarizados com a tarefa a ser realizada (observar se estava contraindo os músculos da mastigação).

Em um teste piloto, os pacientes foram apresentados a um aplicativo de *smartphone*, o BruxApp® (equipe BruxApp, Pontedera, Itália). No entanto, devido à dificuldade de alguns pacientes em utilizar o BruxApp® e por não ser um aplicativo grátis, além da tentativa de utilizar uma versão similar em português, chamada "Desencoste seus dentes", um pesquisador ficou responsável por utilizar o aplicativo BruxApp® e, a cada alerta recebido, o mesmo pesquisador enviava uma mensagem via WhatsApp® para cada paciente. A escolha pelo Whatsapp® se deu pelo fato de ser um aplicativo de mensagens instantâneas gratuito e amplamente utilizado no Brasil. Os pacientes recebiam uma mensagem perguntando se estavam contraindo os músculos mastigatórios, independentemente de estarem ou não tocando seus dentes naquele momento (por exemplo, "você está sentindo que seus músculos mastigatórios estão rígidos/tensos neste momento"?). Os pacientes foram orientados a responder apenas "sim" ou "não".

No teste piloto, foram enviados cerca de 16 perguntas por dia; entretanto, percebeu-se que a adesão dos pacientes ao EMA foi drasticamente reduzida. Para evitar a desistência dos pacientes e, consequentemente, a redução da amostra e, ainda, focar nos pacientes que contraíam os músculos com maior frequência, eram enviadas três perguntas ao dia (uma pela manhã, à tarde e outra à noite), em intervalos aleatórios, que podiam ser enviadas desde as 8h às 12h e das 14h às 22h, durante cinco dias da semana, uma vez que a taxa de resposta não é diferente durante a semana ou finais de semana (Collona et al., 2020).

O paciente deveria responder à mensagem dentro de 5 minutos. Caso contrário, a pergunta era enviada novamente. Dias adicionais foram aplicados até que cada paciente respondesse 100% do total das perguntas (n = 15).

Eletromiografia de Superfície (EMG)

O eletromiógrafo da marca Delsys® (Trigno Wireless System®) ajustado com uma frequência de aquisição de 2000Hz foi utilizado como instrumento de captação da ativação dos músculos temporal anterior e masseter, bilateralmente. O local da pele de colocação de cada sensor passou por uma depilação e limpeza com álcool 70%. A fixação dos eletrodos foi feita por meio de adesivos dupla face fornecidos pelo próprio fabricante do equipamento (Delsys®, Trigno Wireless System®). Foram utilizados eletrodos simples diferenciais wireless, que contém duas barras de prata pura de 10 mm de comprimento por 1 mm de largura cada, posicionadas paralelamente com distância inter eletrodo de 10 mm. Para melhor localização dos músculos foi solicitado sua contração – prova de função muscular (Berni et al., 2015a). O exame seguiu as recomendações da International Society of Electrophysiology and Kinesiology (ISEK).

Os sinais eletromiográficos coletados foram amostrados de forma sincrônica e armazenados para posterior visualização e processamento. Para a aquisição e armazenamento em arquivos de dados dos sinais digitalizados, foi utilizado o software do próprio fabricante do equipamento. A análise foi realizada no domínio da amplitude, para obtenção dos valores de RMS (µV).

A coleta foi realizada em sala climatizada, com temperatura controlada mantida a 23º ± 2ºC. Para a coleta do sinal eletromiográfico, os pacientes foram orientados a sentar-se em uma cadeira com os pés apoiados no chão, as mãos nos membros inferiores (joelho e quadril a 90°) e o olhar paralelo ao solo, respeitando a Plano de Frankfurt. Inicialmente, os pacientes foram solicitados a relaxar por cinco segundos com os olhos fechados e, caso ocorresse a deglutição, a coleta era rejeitada e repetida (Ries et al., 2016).

Para a coleta de isometria (figura 1), os voluntários foram familiarizados previamente com a tarefa. Foi utilizada uma folha de Parafilm M® dobrada três vezes no comprimento e posteriormente ao meio na largura, os voluntários posicionaram o Parafilm M® sobre as faces oclusais do primeiro e segundo molar superior e inferior, bilateralmente durante a coleta, a fim de proteger os dentes (Berni et al., 2015b; Pitta et al., 2015; Ap Biasotto-Gonzalez et al., 2010). Foram solicitadas duas repetições de contração voluntária máxima por 10 segundos de duração cada, com um intervalo de um minuto entre elas (Ernberg et al., 2017).

Para a coleta de isotonia (figura 2) os pacientes foram treinados previamente para a tarefa de mastigação não habitual. Foi utilizada uma folha de Parafilm M® dobrada como mencionado anteriormente. Os pacientes deveriam posicionar o Parafilm M® sobre as faces oclusais do primeiro e segundo molar superior e inferior, bilateralmente durante a coleta, a fim de proteger os dentes (BERNI et al., 2015a; PITTA et al., 2015b). Foi orientado que realizassem a mastigação não habitual com o Parafilm M®, de forma que fosse feita mordida bilateral, seguida de abertura da boca, o suficiente para perda de contato das faces oclusais. A mastigação não habitual foi realizada sem o contato labial. Foram feitas duas repetições de mastigação não habitual com 20 segundos de duração. Quando houve deglutição durante a isotonia, a coleta foi interrompida e coletada novamente. A mastigação não habitual foi feita de acordo com o ritmo do metrônomo digital MA-30 marca KORG (New Market, Estados Unidos), regulado em 60 batimentos por minuto, sob o comando verbal de: “morde, morde, morde...” (Briesemeister et al., 2013). A cada repetição da mastigação, 20 ciclos completos de mordida/abertura da boca foram realizados, ou seja, um ciclo por segundo de acordo com o ritmo pré-determinado.

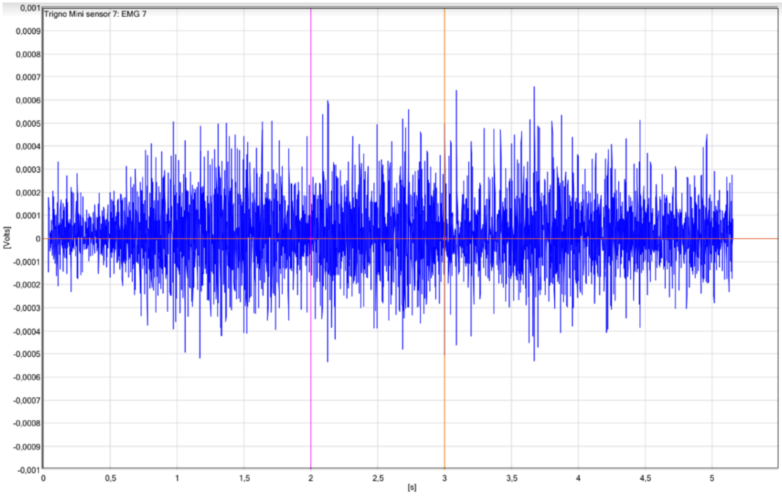

Figura 1. Coleta de isometria extraída da eletromiografia de superfície.

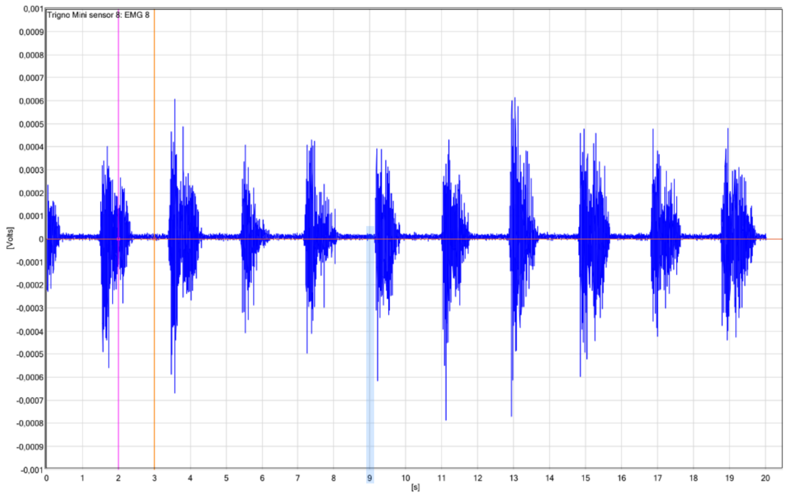

Figura 2. Coleta de isotonia extraída da eletromiografia de superfície.

Os dados EMG foram processados off-line por meio do software Matlab® 8.5.0.1976.13 (R2015a, MathWorks Inc., Natick, Massachusetts, USA). Foi aplicado um filtro digital do tipo Butterworth de 4ª ordem, com atraso de fase zero, com passa alta de 10 Hz e passa baixa de 400 Hz. Ainda, para o processamento do sinal foi utilizado um janelamento da fase de mordida e outro da fase de abertura da boca de cada ciclo, sendo coletado o valor médio de Root Mean Square (RMS).

Desta forma, foi realizada a média da soma de todos os valores de RMS, dos seis ciclos, durante a fase de mordida e de abertura da boa. Todos os músculos iniciavam e encerravam a contração da fase de mordida simultaneamente, não ocorrendo alterações no momento do disparo da ativação das unidades motoras nos músculos agonistas da fase de mordida.

Os seis ciclos mastigatórios centrais de cada coleta no sinal EMG foram considerados para evitar interferências que poderiam ter ocorrido nos primeiros e últimos ciclo de cada coleta, garantindo também a padronização do sinal analisado. Em um estudo piloto, a confiabilidade foi analisada durante as fases de mordida e abertura da boca, comparando as análises intra (0,76≤ICC≥0,98) e interavaliadores (0,78≤ICC≥0,99), que apresentaram confiabilidade boa a excelente, demonstrando que os dados são confiáveis e podem ser analisados por diferentes avaliadores sem alterar o resultado.

Foi realizada a normalização do sinal eletromiográfico dos músculos mastigatórios, utilizando para tal o valor RMS da fase de mordida ou abertura da boca referente ao segundo ciclo de cada sinal coletado. Esta forma de normalização apresentou o menor coeficiente de variação em comparação com outras formas de normalização testadas em estudo piloto.

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ANEXO 1

My other records

These are records that have either been published or rejected and are not currently being worked on.

ID	Title	Status	Last edited
CRD42020136588	CBCT and Panoramic Radiography for the evaluation of marginal bone resorption or external root resorption involving the second molar adjacent to an impacted third molar: a systematic review	Registered	09/02/2021

Disponível em: https://www.crd.york.ac.uk/prospero/#myprospero

ANEXO 2

THE JOANNA BRIGGS INSTITUTE

JBI Critical Appraisal Checklist for Studies Reporting Prevalence Data

Reviewer_____________________________ Date_____________________________

Author _____________________________ Year_______ Record Number__________

	Yes	No	Unclear	Not applicable
1. Was the sample frame appropriate to address the target population?	☐	☐	☐	☐
2. Were study participants sampled in an appropriate way?	☐	☐	☐	☐
3. Was the sample size adequate?	☐	☐	☐	☐
4. Were the study subjects and the setting described in detail?	☐	☐	☐	☐
5. Was the data analysis conducted with sufficient coverage of the identified sample?	☐	☐	☐	☐
6. Were valid methods used for the identification of the condition?	☐	☐	☐	☐
7. Was the condition measured in a standard, reliable way for all participants?	☐	☐	☐	☐
8. Was there appropriate statistical analysis?	☐	☐	☐	☐
9. Was the response rate adequate, and if not, was the low response rate managed appropriately?	☐	☐	☐	☐

Overall appraisal: Include ☐ Exclude ☐ Seek further info ☐

Comments (Including reason for exclusion)

ANEXO 3

Risk of bias assessed by Meta-Analysis of Statistics Assessment and Review Instrument (MAStARI) critical appraisal tools. Risk of bias was categorized as high when the study reaches up to 49% score “yes”, moderate when the study reached 50% to 69% score “yes”, and low when the study reached more than 70% score “yes”

(Question Analytical Cross Sectional Studies)	Oenning et al, 2014[2]	D’Costa et al, 2017[8]	Matzen et al, 2017[17]	Dias et al., 2020[18]	Mendonça et al., 2020[19]
1. Were the criteria for inclusion in the sample clearly defined?	Y	Y	Y	Y	Y
2. Were the study subjects and the setting described in detail?	Y	N	Y	Y	N
3. Was the exposure measured in a valid and reliable way?	Y	Y	Y	Y	Y
4. Were objective, standard criteria used for measurement of the condition?	Y	Y	Y	Y	Y
5. Were confounding factors identified?	Y	N	Y	Y	NA
6. Were strategies to deal with confounding factors stated?	Y	N	Y	Y	NA
7. Were the outcomes measured in a valid and reliable way?	Y	Y	Y	Y	Y
8. Was appropriate statistical analysis used?	Y5	Y	Y	Y	Y
%Yes/Risk	100	62.5	100	100	83.3
Overall	Low	Moderate	Low	Low	Low

*Y=Yes, N=No, U=Unclear, NA=Not applicable

ANEXO 4

Lista de Verificação dos Comportamentos Orais (OBC)

Com qual frequência você fez cada uma das seguintes atividades, baseado **no último mês**? Se a frequência das atividades variar, escolha a opção mais frequente. Marque (x) em uma resposta para cada item e não pule nenhum item. Se você mudar de ideia, preencha a marcação incorreta completamente e, em seguida, marque (x) na nova resposta.

	Atividades durante o sono	Nenhuma vez	<1 noite/ mês	1-3 noites/ mês	1-3 noites/ semana	4-7 noites/ semana
1	Aperta ou range os dentes **quando está dormindo**, baseado em qualquer informação que você possa ter.	☐	☐	☐	☐	☐
2	Dorme numa posição que coloque pressão sobre a mandíbula (por exemplo, de barriga para baixo, de lado).	☐	☐	☐	☐	☐
	Atividades durante a vigília (acordado)	**Nunca**	**Uma pequena parte do tempo**	**Alguma parte do tempo**	**A maior parte do tempo**	**O tempo todo**
3	Range os dentes **quando está acordado**	☐	☐	☐	☐	☐
4	Aperta os dentes **quando está acordado**	☐	☐	☐	☐	☐
5	Pressiona, toca ou mantém os dentes em contato além de quando está comendo (ou seja, faz contato entre dentes superiores e inferiores).	☐	☐	☐	☐	☐
6	Segura, enrijece ou tensiona os músculos, sem apertar ou encostar os dentes.	☐	☐	☐	☐	☐
7	Mantém ou projeta a mandíbula para frente ou para o lado	☐	☐	☐	☐	☐
8	Pressiona a língua com força contra os dentes	☐	☐	☐	☐	☐
9	Coloca a língua entre os dentes	☐	☐	☐	☐	☐
10	Morde, mastiga, ou brinca com a língua, bochechas ou lábios	☐	☐	☐	☐	☐
11	Mantém a mandíbula em posição rígida ou tensa, tal como para segurar ou proteger a mandíbula	☐	☐	☐	☐	☐
12	Segura entre os dentes ou morde objetos, como cabelo, cachimbo, lápis, canetas, dedos, unhas, etc	☐	☐	☐	☐	☐
13	Faz uso de goma de mascar (chiclete)	☐	☐	☐	☐	☐
14	Toca instrumento musical que envolve o uso da boca ou mandíbula (por exemplo, instrumentos de sopro, metal ou corda)	☐	☐	☐	☐	☐
15	Inclina com a mão na mandíbula, tal como se fosse colocar ou descansar o queixo na mão	☐	☐	☐	☐	☐
16	Mastiga os alimentos apenas de um lado	☐	☐	☐	☐	☐
17	Come entre as refeições (ou seja, alimento que requer mastigação)	☐	☐	☐	☐	☐
18	Fala prolongadamente (por exemplo, ensinando, vendas, atendimento ao cliente)	☐	☐	☐	☐	☐
19	Canta	☐	☐	☐	☐	☐
20	Boceja	☐	☐	☐	☐	☐
21	Segura o telefone entre a cabeça e os ombros	☐	☐	☐	☐	☐

ANEXO 5

UNICAMP - FACULDADE DE ODONTOLOGIA DE PIRACICABA DA UNIVERSIDADE DE CAMPINAS - FOP/UNICAMP

PARECER CONSUBSTANCIADO DO CEP

DADOS DA EMENDA

Título da Pesquisa: UTILIZAÇÃO DA TOMOGRAFIA DE FEIXE CÔNICO PARA INVESTIGAÇÃO DE SINAIS DE SOBRECARGA OCLUSAL EM PACIENTES COM E SEM REABSORÇÃO RADICULAR DECORRENTE DE IMPACTAÇÃO DENTÁRIA

Pesquisador: Anne Caroline Costa Oenning

Área Temática:

Versão: 7

CAAE: 41652015.7.0000.5418

Instituição Proponente: Faculdade de Odontologia de Piracicaba - Unicamp

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 3.812.755

Pesquisadores	61DecPesqEmenda.pdf	19:19:36	Souza	Aceito
Outros	72AnexoEmenda.pdf	18/09/2019 19:15:03	Larissa Moreira de Souza	Aceito
Outros	ExclusaoPesq2.pdf	20/02/2017 17:32:04	Anne Caroline Costa Oenning	Aceito
Outros	ExclusaoPesq1.pdf	20/02/2017 17:30:53	Anne Caroline Costa Oenning	Aceito
Outros	71AnexoEmenda.doc	20/02/2017 17:26:51	Anne Caroline Costa Oenning	Aceito
Declaração de Instituição e Infraestrutura	64DeclnfraEmenda.pdf	20/02/2017 17:25:38	Anne Caroline Costa Oenning	Aceito
Declaração de Instituição e Infraestrutura	autorização para uso de arquivos.pdf	12/03/2015 16:48:44		Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

PIRACICABA, 28 de Janeiro de 2020

ANEXO 6

DO

DMFR Office <em@editorialmanager.com>

Sex, 20/08/2021 05:00

Para: Você

CC: "Luciana Butini Oliveira" luciana.oliveira@slmandic.edu.br, "Hugo Gaêta-Araujo" hugo.gaeta@unifal-mg.edu.br, "Marcia Almeida-Marques" marcia.marx@hotmail.com, "Luciana Asprino" asprino@fop.unicamp.br, "Anne Caroline Oenning" anne.oenning@slmandic.edu.br

Dear Moreira-Souza,

I am pleased to inform you that your paper "Comparison of panoramic radiography and CBCT for the assessment of external root resorption and marginal bone loss of second molar associated with third molar impaction: a systematic review" has been accepted in its present form for exclusive publication in Dentomaxillofacial Radiology.

You will receive proofs in due course.

ANEXO 7

MB

Michael Bornstein <michael.bornstein@unibas.ch>

Ter, 08/02/2022 05:15

Para: Você; Tami Potten; Sara Purdy

Dear colleague,

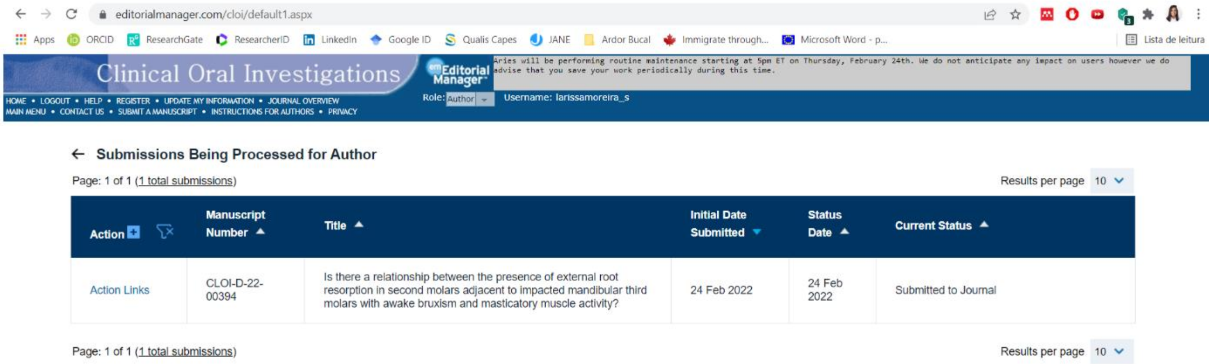
Thank you very much for your message, and also query. I do not see any issues in including your DMFR publication in a presentation or in your PhD thesis as long as it is properly referenced.

My best regards,

Michael Bornstein

Prof. Dr. med. dent. Michael Bornstein

ANEXO 8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Clinical Oral Investigations

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Submissions Being Processed for Author

Page: 1 of 1 (1 total submissions)   Results per page 10

Action	Manuscript Number	Title	Initial Date Submitted	Status Date	Current Status
Action Links	CLOI-D-22-00394	Is there a relationship between the presence of external root resorption in second molars adjacent to impacted mandibular third molars with awake bruxism and masticatory muscle activity?	24 Feb 2022	24 Feb 2022	Submitted to Journal

Page: 1 of 1 (1 total submissions)   Results per page 10

ANEXO 9

VERIFICAÇÃO DE ORIGINALIDADE E PREVENÇÃO DE PLÁGIO

Tese

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