Third Molar and Their Relationship with Caries on the Distal Surface of Second Molar: A Meta-analysis

José Cristiano Ramos Glória³ · Carolina Castro Martins¹ · Anna Catharina Vieira Armond³ · Endi Lanza Galvão² · Cássio Roberto Rocha Dos Santos³ · Saulo Gabriel Moreira Falci^{3,4}

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Abstract

Purpose The aim of this meta-analysis was to determine which characteristics of mandibular third molars (MTMs) are more often associated with an increase in the prevalence/incidence of caries on the distal surface of mandibular second molars (MSMs).

Methods Three electronic databases were analyzed: PubMed; OVID and the Virtual Health Library. Observational studies were included, and the risk of bias was assessed using The Newcastle–Ottawa Scale. The Comprehensive Meta-Analysis software program was used for meta-analysis.

Results Fifteen studies were included in this systematic review, and five were included in the meta-analysis. The distal surface of MSMs were more likely to exhibit caries in the following scenarios: when MTMs were found in the A position, rather than the C position (OR: 3.45, 95% CI: 2.28–5.22, $p < 0.001$); when the horizontal position was compared with the vertical (OR: 8.12, 95% CI: 3.75–17.58, $p < 0.001$) and distoangular (OR: 9.75, 95% CI: 3.49 – 27.25, $p < 0.001$) positions; and when the mesioangular position was compared with the vertical (OR: 7.25, 95%

CI: 3.48–15.10, $p < 0.001$) and distoangular (OR: 9.54, 95% CI: 3.47 – 26.21, $p < 0.001$) positions.

Conclusion The results of this study suggest that the presence of MTMs increases the incidence of caries on the distal surface of MSMs. Furthermore, caries on the distal surface of MSMs is more commonly associated with position A and horizontal and mesioangular mandibular molars.

Keywords Molar · Third · Dental caries · Oral surgery · Impacted tooth

Introduction

The surgical removal of mandibular third molars (MTMs) is one of the most common procedures in oral and maxillofacial surgery [1]. In the past, the presence of an included or impacted tooth with no associated pathologies led to its extraction. Oral and maxillofacial surgeons call this procedure the prophylactic removal of third molars [2], which is used to prevent the development of pathologies such as cysts [3], pericoronitis [4], periodontal diseases [5] and caries [6].

Nowadays, clinical practice in the field of dentistry and medicine is based on scientific evidence, and the prophylactic removal of MTMs has been discouraged [7, 8]. This perspective changed due to the possibility of postoperative complications, including severe pain, edema, bleeding, alveolitis, paresthesia and trismus [9, 10]. However, it remains unclear whether this contraindication is pertinent when considering the association between the existence of MTMs and the presence of distal caries on second mandibular molar (MSMs).

The prevalence of caries on the distal surface of MSMs, associated with a semi-erupted MTM, can range from 7 to 32% [11–14]. Studies of this condition have reported that

✉ Saulo Gabriel Moreira Falci
saulofalci@hotmail.com

¹ Department of Pediatric Dentistry and Orthodontics, Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, Brazil

² Centro de Pesquisas René Rachou, Fundação Oswaldo Cruz, Belo Horizonte, Brazil

³ Department of Dentistry, Universidade Federal dos Vales do Jequitinhonha e Mucuri (UFVJM), Rua da Glória, 187, Diamantina, MG 39100-000, Brazil

⁴ Hospital Santa Casa de Caridade de Diamantina, Diamantina, Brazil

the angulation of the MTM could favor the presence of caries on the distal surface of the MSM [6, 11, 13, 15]. As well as the angulation, gender and the period of exposure of the MTM in the mouth may be correlated with a high prevalence [6]. Thus, it is important to use a scientific evidence-based approach to establish which variables increase the prevalence of caries on the distal surface of MSMs, in the presence of a MTM, thereby justifying their prophylactic removal.

The aim of the present systematic review was to use scientific evidence to determine which positioning characteristics of MTMs are more closely associated with a greater prevalence/incidence of distal caries on MSMs.

Methods

This study did not require the approval of an ethics committee as it is a systematic review.

This systematic review was registered in the PROSPERO database, an international prospective register of systematic reviews (National Institute for Health Research, UK; protocol: CRD42015029916).

Search Strategy

The meta-analysis was conducted in accordance with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) [16] checklist, and the PECO question was established. A search was conducted in the PubMed, OVID and Virtual Health Library (VHL) databases up to December of 2015, without language restrictions.

The keywords were introduced into DeCs (Health Sciences Descriptors) and Mesh (Medical Subject Headings). The following terms were used for each database: PubMed: “Molar, Third AND Dental caries” and “Tooth, Impacted AND Dental caries”; OVID: “Third Molar* AND Dental Caries*” and “Impacted tooth* AND Dental Caries*”; VHL: “Third molar AND Dental caries.”

In order to find articles that were not yet indexed, a manual search of journals addressing oral and maxillofacial surgery was also conducted using the same terms, in the following annals of maxillofacial surgery: the British Journal of Oral and Maxillofacial Surgery; the International Journal of Oral and Maxillofacial Surgery; the Journal of Oral and Maxillofacial Surgery; the Journal of Maxillofacial and Oral Surgery, Medicine and Pathology; the Journal of Craniofacial Surgery; the Journal of Cranio-maxillofacial Surgery; the Journal of Maxillofacial and Oral Surgery; the Journal of Oral and Maxillofacial Research, Oral and Maxillofacial Surgery; Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology. After the search had been completed, the list of references from

all of the articles included was analyzed to obtain any additional studies that were not found in the electronic search.

Selection Criteria

The articles were systematically selected by the reviewers according to specific selection criteria and the criteria established by the PECO Index: (1) population: patients with mandibular third and second molars; (2) exposure: the presence and position of third molars; (3) comparison: the influence of the third molar and its position on the prevalence of distal caries on second molars; (4) outcome: caries on the distal surface of second molars. The following inclusion criteria were applied: observational studies (cross-sectional, cohort or case-control studies) that used diagnostic imaging to analyze the existence of caries on the distal surface of MSMs in association with the presence of MTMs. The following exclusion criteria were applied: didactic books; technical notes; case reports; opinion articles; letters to editors; literature reviews; abstracts; studies involving animals; and studies that did not contain an abstract in the databases.

Study Selection

The study selection process was conducted by two independent authors in three stages: (1) reading titles and abstracts; (2) reading full articles; (3) assessment of the inclusion of articles. Firstly, all the titles and abstracts from the manuscripts identified in the search were read. Articles that did not fulfill the established inclusion criteria were excluded. Those that did fulfill the inclusion criteria were read in full, prior to the final selection of studies. Differences in opinion concerning the inclusion and exclusion of articles were decided between the two investigators. When an agreement could not be reached, a third investigator was consulted to obtain a final decision (Fig. 1).

Data Extraction and Meta-analysis

The following data were extracted from the articles that were selected after a full reading: the author; the year of publication; the country; the study design; the diagnostic methods used for caries; the characteristics of the sample (size and gender); the variables related to the presence or absence of caries; (a) the Pell & Gregory classification for the occlusal plane: A, B, C; (b) the Pell & Gregory classification for the mandibular ramus: I, II, III; (c) the Winter classification: vertical, horizontal, mesioangular, distoangular, inverted; (d) the angulation; and (e) the distance from the MSM (Table 1). If any of the information required was missing, the authors were contacted by

Fig. 1 Screening of studies

e-mail. Subsequently, the data were tabulated independently in electronic forms, prior to the statistical analysis.

Version 2 of the Comprehensive Meta-Analysis software program was used for the meta-analysis [17]. The heterogeneity of studies was assessed using the I^2 test [18]. A sensitivity test was conducted when heterogeneity was greater than 50% [17]. When homogeneity was present ($I^2 = 0.00$), the fixed effect model was used. When heterogeneity was present ($I^2 > 0$), the random effect model was used for the meta-analysis [17, 18]. Risk measures, the 95% confidence interval (CI) and the p value were described in a forest plot. Summary risk measures were also calculated. Publication bias was not assessed as there were not enough studies to be grouped in a funnel plot [19, 20].

Risk of Bias Analysis

The Newcastle–Ottawa Scale [21] was used to assess the quality of the method for case–control and cohort studies (Table 2). A modified version of the Newcastle–Ottawa Scale was used for cross-sectional studies (Table 3) [22]. The following criteria were used to assess the methodological quality of the articles: selection, comparability and

exposure, for case–control studies; and selection, comparability and outcome, for cohort and cross-sectional studies.

Questions were applied for each of these items and the article being assessed received one or two points (stars/*), depending on whether the criterion being assessed was satisfied or not. For cohort and case–control studies, the result of the assessment ranged from 0 (lowest score) to 9 (highest score). For cross-sectional studies, the result of the assessment ranged from 0 (lowest score) to 10 (highest score).

Results

The database search generated a total of 1868 articles. After screening the studies, as described in methods section, a total of 15 articles were included in the systematic review. Of these 15, five were included in the meta-analysis (Fig. 1). Of the 15 articles selected, 11 were cross-sectional studies, three were cohort studies, and one was a case–control study.

The data extraction generated a table which shows the results for the cross-sectional studies (Table 1). The cohort

Table 1 Data extraction of the main features of the selected papers

Author	Falci	Kang	Ozeç	McArdle	McArdle	Chu	Chang	Polat	Silva	Akarslan	Allen
Year of publication	2012	2015	2009	2005	2014	2003	2009	2008	2015	2009	2009
Country	Brazil	China	Turkey	UK	UK	China	Korea	Turkey	Brazil	Turkey	England
Study design	CS	CS	CS	CS	CS	CS	CS	CS	CS	CS	CS
Diagnosis methods	Per	CT	Pan	Pan	Pan	Pan	Pan	Pan	Pan	Pan	Pan
Sample characteristics											
Size	246	469	485	100	239	7486	786	1914	120	342	439
Gender											
Female	177	263	NR	59	97	1.6	477	1086	100	167	NR
Male	69	206	NR	41	142	1	309	828	57	175	NR
Classification											
Pell & Gregory related to the occlusal plane											
With caries <i>n</i> (%)	A	25(13.9)		109(67.7)	NR	NR	NR	125(82.2)	215(56.13)	NR	NR
	B	8(12.1)		137(45.5)	NR	NR	NR	27(17.8)	151(39.42)	NR	NR
	C	NR		14(36.8)	NR	NR	NR	0(0)	17(4.45)	NR	NR
Without caries <i>n</i> (%)	A	155(86.1)		52(32.3)	NR	NR	NR	462(61.8)	1409(52.83)	NR	NR
	B	58(87.9)		164(54.5)	NR	NR	NR	252(34.5)	898(33.67)	NR	NR
	C	NA		24(63.2)	NR	NR	NR	27(3.7)	360(13.50)	NR	NR
Outcome		$p = 0.719$		$p < 0.001$	NR	NR	$p < 0.001$		NR	NR	NR
Pell & Gregory related to the mandibular ramus											
With caries <i>n</i> (%)	I	23(26.7)		NR	NR	NR	NR	NR	NR	NR	NR
	II	10(8.1)		NR	NR	NR	NR	NR	NR	NR	NR
	III	0		NR	NR	NR	NR	NR	NR	NR	NR
Without caries <i>n</i> (%)	I	63(73.3)		NR	NR	NR	NR	NR	NR	NR	NR
	II	113(91.9)		NR	NR	NR	NR	NR	NR	NR	NR
	III	37(100)		NR	NR	NR	NR	NR	NR	NR	NR
Outcome		$p < 0.001$		NR	NR	NR	NR	NR	NR	NR	NR
Winter											
With caries <i>n</i> (%)	Vertical	9(6.1)		NR	NR	NR	NR	NR	41(2.7)	15(9.55)	NR
	Horizontal	8(19.0)		NR	NR	NR	NR	NR	133(23.8)	5(3.18)	NR
	Mesioangular	16(37.2)		NR	NR	NR	NR	NR	206(23.3)	20(12.73)	42%
	Distoangular	0		NR	NR	NR	NR	NR	3(3.6)	0(0)	NR
	Inverted	NR		NR	NR	NR	NR	NR	0(0)	NR	NR

Table 1 continued

Classification										
Without caries <i>n</i> (%)	Vertical	139(93.9)	NR	NR	NR	NR	NR	1465(97.3)	75(47.77)	NR
	Horizontal	34(81)	NR	NR	NR	NR	NR	426(76.2)	2(1.27)	NR
	Mesioangular	27(62.8)	NR	NR	NR	NR	NR	677(76.7)	30(19.10)	NR
	Distoangular	13(100)	NR	NR	NR	NR	NR	81(96.4)	10(6.36)	NR
	Inverted	NR	NR	NR	NR	NR	NR	18(100)	NR	NR
Outcome		$p < 0.001$	NR	NR	NR	NR	NR	$\chi^2 = 298.99$	NR	$p < 0.001$
Classification										
Angulation										
With caries <i>n</i> (%)	–32 to –1	5(6.4)	42°–43°	47 (30.9)	NR	NR	NR	<0°	1(0.7)	NR
	0 to 29	7(6.9)	43°–73°	143 (76.1)	NR	NR	NR	0°–20°	7(4.6)	NR
	31 to 108	45(68.2)	73°–126°	70 (43.8)	NR	NR	NR	21°–40°	12(7.9)	NR
Without caries <i>n</i> (%)	–32 to –1	73(93.6)	42°–43°	105(69.1)	NR	NR	NR	41°–60°	50(32.9)	NR
	0 to 29	95(93.1)	43°–73°	45 (23.9)	NR	NR	NR	61°–80°	71(46.7)	NR
	31 to 108	45(68.2)	73°–126°	90 (56.2)	NR	NR	NR	>80°	11(7.2)	NR
	–32 to –1	73(93.6)	42°–43°	105(69.1)	NR	NR	NR	<0°	87(11.9)	NR
	0 to 29	95(93.1)	43°–73°	45 (23.9)	NR	NR	NR	0°–20°	90(12.3)	NR
Distance	1–2 mm	9(7.5)	0–6 mm	37(29.6)	NR	NR	NR	21°–40°	51(7.0)	NR
	3–10 mm	24(19.0)	6–8 mm	129(71.7)	NR	NR	NR	41°–60°	143(19.0)	NR
	1–2 mm	111(92.5)	0–6 mm	105(69.1)	NR	NR	NR	61°–80°	248(33.9)	NR
Without caries <i>n</i> (%)	1–2 mm	9(7.5)	0–6 mm	37(29.6)	NR	NR	NR	>80°	112(15.3)	NR
	3–10 mm	24(19.0)	6–8 mm	129(71.7)	NR	NR	NR	$p < 0.001$	NR	NR
	1–2 mm	111(92.5)	0–6 mm	105(69.1)	NR	NR	NR	1–3 mm	9(5.9)	NR
	3–10 mm	102(81.0)	6–8 mm	45(23.9)	NR	NR	NR	4–6 mm	25(16.4)	NR
	1–2 mm	111(92.5)	0–6 mm	105(69.1)	NR	NR	NR	7–9 mm	87(57.2)	NR
Outcome	1–2 mm	111(92.5)	0–6 mm	105(69.1)	NR	NR	NR	30(19.7)	NR	NR
	3–10 mm	102(81.0)	6–8 mm	45(23.9)	NR	NR	NR	1(0.7)	NR	NR
	1–2 mm	111(92.5)	0–6 mm	105(69.1)	NR	NR	NR	1–3 mm	158(21.6)	NR
	3–10 mm	102(81.0)	6–8 mm	45(23.9)	NR	NR	NR	4–6 mm	195(26.7)	NR
	1–2 mm	111(92.5)	0–6 mm	105(69.1)	NR	NR	NR	7–9 mm	320(43.8)	NR
Outcome		$p = 0.008$	$p < 0.001$	$p < 0.05$	NR	NR	NR	56(7.7)	NR	NR
								2(0.3)	NR	NR
								NR	NR	NR

UK UK, CS cross-sectional, *Per* periapical radiograph, *CT* computed tomography, *Pan* panoramic radiograph, *NR* not reported

Table 2 Assessment of the risk of bias of the studies according to modified version of the Newcastle–Ottawa Scale²²

Studies			Venta, 1993 Cohort	Nunn, 2013 Cohort	Huang, 2014 Cohort	Oderinu, 2012 Case– control
Study design						
Selection One star (*) was given for each question	Related to:	(1) Is the case definition adequate?	–	–	–	a*
	Case–control	(a) Yes, with independent validation*				
	Case–control	(b) Yes, record linkage or based on self-reports				
	Case–control	(c) No description				
	Related to:	(2) Representativeness of the sample	–	–	–	a*
	Case–control	(a) Consecutive or obviously representative series of cases*				
	Case–control	(b) Potential for selection biases or not stated				
	Related to:	(3) Representativeness of the exposed cohort	c	b*	c	–
	Cohort	(a) Truly representative of the average in the community*				
	Cohort	(b) Somewhat representative of the average in the community*				
	Cohort	(c) Selected group of users or no description				
	Related to:	(4) Selection of controls	–	–	–	a*
	Case–control	(a) Community controls*				
	Case–control	(b) Hospital controls				
	Case–control	(c) No description				
	Related to:	(5) Definition of controls	–	–	–	a*
	Case–control	(a) No history of diseases (endpoint)*				
	Case–control	(b) No description of source				
	Related to:	(6) Selection of non-exposed cohort	a*	a*	a*	–
	Cohort	(a) Drawn from the same community as the exposed cohort*				
	Cohort	(b) Drawn from a different source				
	Cohort	(c) No description of the derivation of the non-exposed cohort				
	Related to:	7) Ascertainment of exposure	a*	a*	a*	–
	Cohort	(a) Secure record*				
	Cohort	(b) Structured interview*				
	Cohort	(c) Written self-report or no description				
	Cohort	8) Demonstration that outcome of interest was not present at start of study	b	a*	a*	–
	Cohort	(a) Yes*				
	Cohort	(b) No				

Table 2 continued²²

Studies			Venta, 1993 Cohort	Nunn, 2013 Cohort	Huang, 2014 Cohort	Oderinu, 2012 Case– control
Study design						
Comparability Up to 2 stars (*) were given for each question	Related to:	(9) Comparability of cases and controls on the basis of the design or analysis.	–	ab**	ab**	–
	Both	(a) Study controls for the most important factor*				
	Both	(b) Study controls for any additional factor *				
Exposure 1 star (*) for each question	Related to:	(10) Ascertainment of exposure	–	–	–	a*
	Case– control	(a) Secure record (e.g., surgical records)*				
	Case– control	(b) Structured interview where blind to case/control status*				
	Case– control	(c) Interview not blinded to case/control status				
	Case– control	(d) Written self-report or medical record only				
	Case– control	(e) No description				
	Case– control	(11) Sample method of ascertainment for cases and controls	–	–	–	a*
	Case– control	(a) Yes*				
	Case– control	(b) No				
	Case– control	(12) Non-response rate	–	–	–	b
	Case– control	(a) Same rate for both groups*				
	Case– control	(b) Non-respondents described				
	Case– control	(c) Rate different and no designation				
Outcome 1 star (*) for each question	Cohort	(13) Assessment of outcome	a*	a*	a*	–
	Cohort	(a) Independent or blind assessment *				
	Cohort	(b) Record linkage*				
	Cohort	(c) Self-report or no description				
	Cohort	(14) Time of follow-up	a*	a*	b	–
	Cohort	(a) Follow-up over 5 years*				
	Cohort	(b) Follow-up under 5 years				
	Cohort	(15) Adequacy of follow-up	b	a*	c	–
	Cohort	(a) Complete follow-up—all subjects accounted for*				
	Cohort	(b) Subjects lost to follow-up unlikely to introduce bias—small number lost < 20% follow-up*				
	Cohort	(c) Follow-up rate < 80% and no description of those lost				
	Cohort	(d) No statement				
	Total		4/9	9/9	6/9	6/9

studies [23–25] exhibited the results for the relative risk of developing caries on the distal surface of the MSM. Nunn et al. [24] conducted cross-sectional analysis at baseline, adjusted for age, smokers and education levels. In this

analysis, the MSMs adjacent to the erupted MTMs were more likely to have caries on the distal surface than those in an environment without MTMs (OR 1.73). In the longitudinal analysis, the relative risk of caries on the distal

Table 3 Assessment of the risk of bias of the studies according to modified Newcastle–Ottawa Scale²²

Studies	Chu, 2003	McArdle, 2006	Polat, 2008	Ozeç, 2009	Chang, 2009	Allen, 2009	Akarslan, 2009	Falci, 2012	McArdle, 2014	Silva, 2015	Kang, 2015
Selection (Maximum 5 stars)											
(1) Representativeness of the sample											
(a) Truly representative of the average in the target population*	b*	c	b*	b*	b*	b*	b*	b*	b*	b*	b*
(b) Somewhat representative of the average in the target population*											
(c) Selected group of users											
(d) No description											
(2) Sample size	b	b	b	b	b	b	b	a*	b	b	b
a) Justified and satisfactory*											
(b) Not justified											
(3) Non-respondents	c	c	c	c	c	c	c	c	c	c	c
(a) Comparability between respondent and non-respondent characteristics is established, and the response rate is satisfactory*											
(b) The response rate is unsatisfactory, or the comparability between respondents and non-respondents is unsatisfactory											
(c) No descriptions											
(4) Ascertainment of the exposure	a**	a**	a**	a**	a**	a**	a**	a**	a**	a**	a**
(a) Validated measurement tool**											
(b) Non-validated measurement tool, but the tool is available or described*											
(c) No description of the measurement tool											
Comparability (Maximum 2 stars)											
(1) The subjects in different outcome groups are comparable, based on the study design or analysis. Confounding factors are controlled	–	–	–	–	–	–	–	b*	–	–	b*
(a) The study control for the most important factor (select one) *											
(b) The study control for any additional factor *											
Outcome (Maximum 3 stars)											
(1) Assessment of the outcome	a**	a**	a**	a**	a**	a**	a**	a**	a**	a**	a**
(a) Independent blind assessment **											
(b) Record linkage **											
c) No description											
(2) Statistical test	b	b	a*	a*	a*	b	a*	a*	b	b	a*
(a) The statistical test used to analyze the data is clearly described and appropriate, and the measurement of the association is present, including confidence intervals and the probability level*											
(b) The statistical test is not appropriate, not described or incomplete.											
Total number of stars for each paper	5/10	4/10	6/10	6/10	6/10	5/10	6/10	8/10	5/10	5/10	7/10

Fig. 2 Meta-analysis for Pell & Gregory classification (A vs. C), $I^2 = 0.0\%$, the fixed effect model used. OR > 1 increased risk of caries for exposed group (A), when compared to group (C)

surface of MSMs was assessed in the following conditions: absence of MTMs (reference, RR 1); eruptions (RR 2.53; 95% CI 1.55–4.14); teeth impacted in soft tissue (RR 0.83; 95% CI 0.11–6.04); and teeth impacted in the bone (RR 1.44; 95% CI 0.55–3.72). In a study conducted by Huang et al. [25], the prevalence of caries on the distal surface of the MSMs of patients who had MTMs removed was 0.2 per 100 people-year (95% CI 0.0–1.4). In a follow-up to this study, the prevalence of caries on the distal surface of MSMs was 0.6 per 100 people-year (95% CI 0.2–1.5). In a cohort study Venta et al. [23] followed up 123 MSMs to evaluate the incidence of caries on distal surface. The results showed that, in the absence of third molar, one MSM developed caries on the distal surface (between the 4th and 6th year of follow-up); one MSM developed caries on the distal surface (between the 1st and 3rd year of follow-up), when the MTM was not erupted; and three MSM developed caries on the distal surface (one between the 1st and 3rd years and two between 4th and 6th years of follow-up) when the MTM was partially erupted.

Oderinu et al. [26] conducted a case–control study assessing the existence of caries on the distal surface of MSMs in two distinct groups: case (impacted MTMs) and control (completely erupted MTMs). No case of caries was found on the distal surface of the MSMs of patients with completely erupted MTMs. The presence of caries was detected in 15.7% of the patients with impacted MTMs ($p < 0.001$).

In the cross-sectional studies, meta-analysis was used to compare the Pell & Gregory positions A, B and C, in terms of the presence or absence of caries. After performing the sensitivity test, only the A x C comparison was indicated. The other comparisons (A x B and B x C) showed a lack of consistency in the sensitivity test, and consequently, meta-analysis was contraindicated. From a total of 3169 cases, the MTMs in group A were more likely to cause caries on the distal surface of MSMs than those in group C (OR 3.45, 95% CI 2.28–5.22, $p < 0.001$) (Fig. 2). The meta-analysis

Fig. 3 Meta-analysis for Winter classification (horizontal vs. distoangular), $I^2 = 0.0\%$, the fixed effect model used. OR > 1 increased risk of caries for exposed group (horizontal), when compared to (distoangular)

Fig. 4 Meta-analysis for Winter classification (horizontal vs. mesioangular), $I^2 = 64.46$, the random effect model used. OR > 1 increased risk of caries for exposed group (horizontal), when compared to (mesioangular)

for Pell & Gregory classification (I, II and III) was not possible, because the papers included did not assess this variable.

Concerning the Winter classification, a total of 2280 cases were included in the meta-analysis. When horizontal MTMs were present, there was a greater prevalence of caries on the distal surface of the MSMs, when compared with the presence of distoangular MTMs (OR 9.75, 95% CI 3.49–27.25, $p < 0.001$) (Fig. 3). No difference was found between the prevalence of caries on the distal surface of the MSMs when comparing horizontal and mesioangular MTMs (OR 0.95, 95% CI 0.40–2.27, $p = 0.906$) (Fig. 4). When mesioangular MTMs were present, there was a greater prevalence of caries on the distal surface of the MSM, when compared with distoangular MTMs (OR 9.54, 95% CI 3.47–26.21, $p < 0.001$) (Fig. 5). When horizontal MTMs were present, there was a greater prevalence of caries on the distal surface of the MSM, when compared with vertical MTMs (OR 8.12, 95% CI 3.75–17.58, $p < 0.001$) (Fig. 6). When mesioangular MTMs were present, there was a greater prevalence of caries on the distal surface of the MSM, when compared with vertical

Fig. 5 Meta-analysis for Winter classification (mesioangular vs. distoangular), $I^2 = 0.0\%$, the fixed effect model used. OR > 1 increased risk of caries for exposed group (mesioangular), when compared to (distoangular)

Fig. 6 Meta-analysis for Winter classification (horizontal vs. vertical), $I^2 = 51.93$, the random effect model used. OR > 1 increased risk of caries for exposed group (horizontal), when compared to (vertical)

Fig. 7 Meta-analysis for Winter classification (mesioangular vs. vertical), $I^2 = 72.14$, the random effect model used. OR > 1 increased risk of caries for exposed group (mesioangular), when compared to (vertical)

MTMs (OR 7.25, 95% CI 3.48–15.10, $p < 0.001$) (Fig. 7). No difference was found between the prevalence of caries on the distal surface of the MSM when comparing the presence of vertical and distoangular MTMs (OR 0.95, 95% CI 0.34–2.66, $p = 0.918$) (Fig. 8). No standardization occurred among the studies in relation to the collection of data for angulation and the distance between second and

Fig. 8 Meta-analysis for Winter classification (distoangular vs. vertical), $I^2 = 0.0\%$, the fixed effect model used. OR > 1 increased risk of caries for exposed group (distoangular), when compared to (vertical)

third molars, which prevented the possible use of meta-analysis. However, in the studies that assessed these variables, it was clear that a more extensive angulation between the long axis of MTMs and MSMs led to a greater presence of caries on the distal surface of the MSM. In addition, a larger distance between the cement–enamel junction of the MTM and the MSM led to a greater presence of caries on the distal surface of the MSM.

Concerning the quality of the three cohort studies, one [23] obtained a total score of four stars (from a maximum of nine), while another [24] obtained a score of nine stars and the third [25] obtained a score of six stars. The case–control study included in this review [26] obtained a score of six stars (Table 2). As for the cross-sectional studies, one study [6] obtained a score of eight stars (from a maximum of ten), while another [27] obtained seven stars, with four obtaining six stars [11, 13, 28, 29], four obtaining five stars [12, 30–32] and one with just four stars [15] (Table 3).

Discussion

The prophylactic removal of included and semi-included MTMs has been addressed frequently in scientific literature and remains controversial to this day. A number of authors recommend prophylactic removal in order to prevent the development of caries [6, 11, 13, 27] and gum disease [33, 34], whereas others claim that there is little evidence to suggest that the removal of these teeth is beneficial [35–38]. The aim of this systematic review was to use scientific data to determine which characteristics of MTMs are risk factors for the presence of caries on the distal surface of MSMs.

Most of the studies found in this systematic review were cross-sectional studies. It was found that the prevalence of caries on the distal surface of MSMs, in the presence of

semi-erupted MTMs, has been studied more than the prevalence. This could be due to the methodological difficulties involved in the performance of cohort and case–control studies. Therefore, the scientific evidence that exists is based on cross-sectional studies, which contain less evidence on the level of the scientific evidence pyramid, when compared with cohort studies.

As well as the fact that there are many more cross-sectional studies available, it is important to note that the methodological quality of the studies can also harm the level of evidence. In this review, we used the Newcastle–Ottawa Scale [21] to assess case–control and cohort studies by means of a 9-star scale. Only one study [24] obtained the maximum score (nine), while two others obtained a score of six [25, 26] and one obtained a score of four [23]. Methodological weaknesses were obvious in these studies, due to the inadequate representativeness of the sample, the time periods and the monitoring protocols [23, 25]. Thus, it is suggested that studies addressing this subject using methods similar to those used by Nunn et al. [24] should be developed in order to determine correlations between the presence of MTMs and the prevalence of caries on the distal surface of MSMs. Cross-sectional studies were assessed using the Newcastle–Ottawa Scale—modified for cross-sectional studies [22], in which a study can obtain a maximum score of ten stars. None of the studies in this review obtained this maximum score. One study scored eight stars [6], while another got seven [27], four got six [11, 13, 28, 29], and five studies only scored five stars or less [12, 15, 30–32]. The most significant methodological flaws detected were: the non-description of non-respondents [6, 11–13, 15, 27–32]; the failure to calculate the sample size [11–13, 15, 27–32]; and the failure to control all confusion factors [11–13, 15, 28–32]. Thus, it is clear that the methodology of most of the studies included was inadequate. We suggest that more observational studies should follow the protocol established by the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [39], in order to obtain a greater understanding of this theme. This instrument provides guidelines on the performance of observational studies and improves the methodological quality of observational studies.

One cohort study [24] reported that the presence of MTMs increases the relative risk of developing caries on the distal surface of MSMs by 2.53, when compared with the absence of MTMs. Conversely, another study [25] with 678 patients reported that only four developed caries on the distal surface of MSMs in the exposed group (presence of a MTM), as opposed to one patient, from a total of 528, who developed caries on the distal surface of the MSM in the non-exposed group (absence of a MTM). Despite the fact that the author did not provide the result, it was possible to

calculate the relative risk of developing caries on the distal surface of MSMs when a MTM is present: RR 3.10. Therefore, despite this study [25] exhibiting a lower quality of methodology and a shorter follow-up period (18 months) than the previous study, the results for the risk of developing caries were similar: RR 2.53²⁴ and RR 3.10 [25]. Consequently, it is clear that the prevalence of caries on the distal surface of MTMs is correlated with the presence of the MTM over time. Since the results of this meta-analysis showed a greater prevalence of caries on the distal surface of MSMs when horizontal and mesioangular MTMs were present (Figs. 3, 5, 6 and 7), cohort studies should be conducted to compare the prevalence of caries on the distal surface of MSMs in groups in which MTMs are either present or absent, using the following categories: 1—(horizontal and mesioangular) and 2—(vertical and distoangular). A study with this design would favor a more adequate understanding of the involvement of horizontal and mesioangular MTMs in the prevalence of this pathology.

Concerning the occlusal plane, the meta-analysis of 3169 participants showed that completely erupted MTMs (class A—Pell & Gregory) are 3.45 times more likely to cause caries on the distal surface of MSMs than non-erupted MTMs (class C—Pell & Gregory). The notion that the presence of MTMs increases the chance of caries occurring on the distal surface of MSMs has been discussed at length in the literature, corroborating the results of this meta-analysis. The authors recommended the prophylactic removal of erupted MTMs in order to reduce the prevalence of caries on the distal surface of MSMs [6, 11, 24, 25, 27, 28]. It seems that the presence of MTMs hinders the cleaning of the region, which, in turn, leads to the appearance of caries on the distal surface of MSMs [6, 27]. Concerning partially erupted MTMs (class B—Pell & Gregory), meta-analysis could not be performed due to the high level of heterogeneity of the results and the lack of consistency in the sensitivity tests. Thus, the correlation between the presence of caries on the distal surface of MSMs when comparing the Pell & Gregory classifications (A vs. B) and (B vs. C) remains unknown. However, the authors that assessed this variable reported that partially erupted MTMs lead to the appearance of caries on the distal surface of MSMs [11, 27, 28].

As well as the eruption status of MTMs, the Winter classification of angulation (horizontal, vertical, mesioangular, distoangular) seems to be the most influential variable in relation to the prevalence of caries on the distal surface of MSMs [6, 27, 28, 32]. Based on the results of the meta-analysis, as well as those from the studies found in the literature, it would appear that horizontal and mesioangular teeth are risk factors for the appearance of caries on the distal surface of MSMs (Figs. 3, 5, 6 and 7).

Thus, the authors recommend the prophylactic removal of semi-erupted, horizontal and mesioangular MTMs [6, 15] in order to prevent the appearance of caries on the distal surface of MSMs. Another variable that has been widely discussed in the literature is the distance of the cement–enamel junction between MTMs and MSMs [6, 11]. The authors of this review believe that this variable is directly proportional to the angulation of MTMs and that horizontal and mesioangular MTMs exhibit a greater cement–enamel distance from MSMs. Consequently, they also cause a greater prevalence of caries on the distal surface of MSMs [6, 11, 27]. One possible explanation for both the angulation and the distance is that when they are both increased, food retention in the region also increases, leading to cleaning issues. Age is generally controlled in studies. The authors stated that the longer the MTMs are exposed in the mouth, the greater the chance of caries occurring on the distal surface of MSMs [6, 11, 13, 27, 30, 31]. This strengthens the argument that the angulation (mesioangular and horizontal) of erupted MTMs is a risk factor that justifies their prophylactic removal, thereby avoiding the appearance of caries over time [6].

This meta-analysis included all studies that assessed the presence of caries on the distal surface of MSMs using imaging methods to assist the diagnosis. Most of the studies assessed the presence of caries using panoramic radiographs [11–13, 15, 28–32]. Only one study assessed the presence of caries using periapical radiography [6] or computed tomography [27]. This underestimation of the prevalence of caries could be one of the most significant limitations of the present systematic review, given that earlier studies have confirmed that the best method of diagnosing caries on posterior teeth is the use of periapical inter-proximal radiographs [40–42]. A recent study used cone beam computed tomography as a diagnostic method [27]. This method exhibited greater sensitivity than traditional intra-oral X-rays when detecting occlusal lesions, providing a better quality of assistance during the diagnosis of caries [43]. Conversely, when caries lesions are analyzed in their initial (non-cavitated) stages, cone beam computed tomography does not provide better results than intra-oral radiographic examinations [44].

Therefore, it is recommended that caries should be diagnosed using more sensitive methods, such as a clinical examination, laser scans [45], intra-oral radiographic examinations [40] and computed tomography, which diagnose the problem at all stages of its evolution. The diagnostic methods used in the studies in this review can be considered a methodological limitation in the meta-analysis, given that only cavitated caries lesions were diagnosed in the imaging examinations.

Therefore, cohort studies that assess the development of caries over time are required in order to more accurately

determine the effect of the presence of MTMs, in their wide range of conditions, on the development of caries on the distal surface of MSMs.

Based on the results of this systematic review, and considering the limitations discussed, it is possible to conclude that the presence of MTMs increases the prevalence of caries on the distal surface of MSMs. Furthermore, the prevalence of caries on the distal surface of MSMs is greater in the presence of class A (Pell & Gregory), horizontal and mesioangular MTMs.

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