

## Review

# Prevalence of distal surface caries in the second molar among referrals for assessment of third molars: a systematic review and meta-analysis

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Accepted 23 April 2019

Available online 23 May 2019

## Abstract

We conducted a systematic review of epidemiological studies to assess the prevalence of distal surface caries (DSC) in second molars adjacent to third molars. We searched the Cochrane Library, Lilacs, Embase, and Medline through Ovid<sup>®</sup> (Wolters Kluwer) to retrieve English and non-English papers from inception to June 2016, and supplemented this with a search of the references and by tracking citations. Three reviewers contributed: one reviewed all the papers, and the other two divided the rest between them. They extracted data, completed structured quality assessments with a validated risk of bias tool for observational studies, and categorised the summary scores. The search yielded 81 records and 11 studies were analysed. The considerable methodological diversity meant that five were not eligible for inclusion in the quantitative synthesis. A meta-analysis of six studies on the prevalence of DSC and a subgroup analysis of three on various third-molar angulations were indicated. The overall pooled prevalence estimate calculated with a random-effects model was 23% (95% CI 2% to 44%) among patients. Prevalence subtotals were 20% (95% CI 5% to 36%) for prospective, and 15% (95% CI 5% to 36%) for retrospective studies among teeth. A subgroup analysis of three studies with 1296 patients (1666 molars) yielded a prevalence of DSC of 36% (95% CI 5% to 67%) for mesial impactions and 22% (95% CI 1% to 42%) for horizontal impactions. DSC was present in 3% of distally-inclined impactions, (95% CI 1% to 5%) and in 7% (95% CI 1% to 13%) of vertical third molars. The studies varied. The risk of bias was low in one and moderate in two. European studies suggested that DSC may be present in about one in four referrals for the assessment of third molars, and that the risk is considerably higher in those with convergent third molar impactions.

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**Keywords:** Third molar; caries; distal surface caries; second molar; prevalence; epidemiology

## Introduction

The retention of lower third molars has been associated with the development of distal caries in the second molar (in the surface of the tooth immediately adjacent to the impacted

wisdom tooth).<sup>1,2</sup> Distal surface caries (DSC) in a second molar that is associated with a retained third molar is also known as distal caries or distal cervical caries, and has been defined as caries that affect the crown, cervical area (amelocemental junction), root, and proximal surfaces of the distal aspect of the second molar.<sup>3,4</sup> Currently, the exact prevalence is unknown and, to the best of our knowledge, the quality of the evidence that supports existing data has not been investigated systematically.<sup>5</sup> DSC leads to poor outcomes for second molars, and some authors have expressed concern that

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the retention of third molars can be more harmful than their prophylactic extraction.<sup>6</sup> Ventä et al<sup>7</sup> showed that removal of the third molar is eventually required in most patients.

Prevalence is one of the most commonly reported epidemiological measures, and it quantifies the burden of a health outcome or disease in a population at a single time point. However, although studies report the prevalence of DSC in second molars, estimates are not consistent, and vary widely from 0%<sup>8</sup> to 51%.<sup>9</sup> Direct comparison is difficult because denominators are differently defined, and a systematic analysis of international prevalence is warranted.

In England and Wales, the National Institute for Health and Care Excellence (NICE)<sup>10</sup> guidelines on third molars have changed since 2000, leading to a suspected increase in the prevalence of DSC. A deliberate strategy of no intervention aims to retain impacted third molars in a pathologically prone state for longer, but predominantly mesioangular and horizontally-inclined mandibular teeth form an inaccessible area distal to the second molar where plaque collects, and long-term retention is thought to raise the susceptibility to DSC considerably. Retention may therefore contribute to the formation of DSC and have a deleterious effect on second molars.<sup>1–5</sup>

In the last decade, several observational studies<sup>4,8,9,11–15</sup> have suggested an increase in the prevalence of DSC among the patients referred to departments of oral and maxillofacial surgery. The main aim of this study therefore, was to review published papers on the prevalence of DSC in second molars that are associated with impacted third molars. Our primary objectives were to quantify its prevalence and to assess the associated risk of bias by systematic review with meta-analysis. The secondary objective was to find out whether this estimate varied according to population (patients attending general practice or hospital), geographical location, demographics, the time at which the study was conducted, characteristics of third molars, and general dental health. The review was conducted according to Meta-analyses of Observational Studies in Epidemiology (MOOSE) standards.<sup>16</sup>

## Material and methods

We aimed to include prospective and retrospective studies that assessed the prevalence of DSC in second molars adjacent to third molars. Full-text studies that reported its incidence in people aged 16 years and over who had had clinical and radiographic examinations, were included. The primary outcome was the development of DSC in the second molar, identified by clinical and radiographic examination. Data were also collected on demographics, type of population (care settings), continent of origin, and year of publication, as well as angulation of the third molar, and general dental health (decayed, missing, filled tooth (DMFT) scores). Prevalence was defined as the number of people or molars with DSC, divided by the number of people or molars studied.<sup>17</sup>

Studies that provided information on different or unspecified patterns of caries, or those that merely described loss of adjacent molars, disease, or patterns of resorption in the second molar (without reference to the distal surface of the crown, cervical area, or root), were excluded. Those that included patients with their primary dentition, or those that provided the incidence without a description of the method used, were also excluded.

We did a comprehensive search of published papers on the prevalence of DSC. The keywords with “wild-cards” and medical subject headings were used in different combinations: “molar”; “wisdom tooth”; “3rd molar”; “third-molar”; “wisdom adj3 t\*\*th”; “distal surface caries”; “distal”; “adj3 caries”; “cervical caries”; “distocervical caries”; “disto-cervical caries”; “second molar\*”; or “2nd molar\*”; “second-molar\*”; “adjacent molar\*”; “approximal caries”; “interproximal caries”; “caries adj3 second”; “root surface”; “decay”; “not secondary”; “incidence”; “prevalence”; “frequency”; “population”; and “proportion”. The following databases were searched from inception to June 2016: Cochrane Library, (Embase, and Medline through the Ovid® (Wolters Kluwer) search platform), and Lilacs.

After the electronic searches and initial selection, we did a supplementary hand search of all the studies identified, tracking citations and checking the references. We also checked those of national guidelines on third molars. There were no restrictions on language or date of publication. All the references identified were compiled into a reference manager (EndNote™ X7, Clarivate Analytics). The titles and abstracts of all the articles identified through the electronic searches were screened by three contributors, and all the papers were reviewed by two. One reviewed them all, the other two divided the rest between them.

Any disagreements were resolved by consultation until mutual agreement was reached. The University of Manchester (UK) provided the statistical analysis and the authors interpreted the results. All the authors substantially contributed to and revised the work for intellectual content and accuracy, and ensured the integrity of the research and that all inquiries were appropriately investigated and answered.

Studies that were not in the English language were translated and assessed. The data were extracted independently using a specifically-designed data extraction form. Any differences were resolved by consultation with all the authors until mutual agreement was reached, and the study characteristics were tabulated in Word (Windows software). One author of an original report was contacted by email for more data on the care setting.<sup>18</sup>

Structured quality assessments were done according to the method designed and validated specifically for prevalence studies by Hoy et al (Table 1).<sup>19</sup> This has two responses to each question: a high and a low risk of bias, which has resulted in high inter-rater agreement.<sup>19</sup> It comprises 10 ques-

Table 1  
Adapted tool for assessment of risk of bias in prevalence studies.<sup>19</sup>

Item	Low risk	High risk
External validity:		
1. Was the study's target population a close representation of the national population in relation to relevant variables?		
2. Was the sampling frame true or a close representation of the target population?		
3. Was some form of random selection used to select the sample, OR was a census undertaken?		
4. Was the likelihood of nonresponse bias minimal?		
Internal validity:		
5. Were data collected directly from the subject (as opposed to a proxy)?		
6. Was an acceptable case definition used in the study?		
7. Was the study instrument that measured the parameter of interest shown to have validity and reliability?		
8. Was the same mode of data collection used for all subjects?		
9. Was the length of the shortest prevalence period for the parameter of interest appropriate?		
10. (Assesses bias related to the analysis)		
11. Were the numerators(s) and denominator(s) for the parameter of interest appropriate?		
Summary assessment	Low risk	Moderate risk
12. Summary item on the overall risk of bias		High risk

Table 2  
Characteristics of excluded studies.

First author, year, and reference	Reason for rejection
Shugars 2004 <sup>20</sup>	Assessed caries in the second molar but not specifically those affecting the distal aspect
Shugars 2005 <sup>21</sup>	Assessed caries in the second molar but not specifically those affecting the distal aspect
Garaas 2012 <sup>22</sup>	Assessed caries in the second molar but not specifically those affecting the distal aspect
Fisher 2012 <sup>23</sup>	Assessed caries in the second molar but not specifically those affecting the distal aspect
Bozzatello 2006 <sup>24</sup>	Assessed caries in the second molar but not specifically those affecting the distal aspect
Alves 2014 <sup>25</sup>	Assesses association between stage of eruption and occlusal caries in second molars among 12-year-old schoolchildren
Ajrish 2015 <sup>26</sup>	Assessed caries in the second molar but not specifically those affecting the distal aspect
Oderinu 2012 <sup>27</sup>	Withdrawn study
McArdle 2006 <sup>28</sup>	Case series of DSC
Nunn 2013 <sup>12</sup>	DSC incidence study
Huang 2014 <sup>29</sup>	DSC incidence study

tions/item assessed (internal/external validity, no response and measurement biases, and bias related to the analysis of data) to provide an overall judgment of the risk (low, moderate, or high).

After consideration of specific key domains, the reviewers produced an overall summary score for each study to complement the individual scores for risk of bias. High risk was a high-risk score in item 2 or 7; moderate risk was a high-risk score in item 3 or 9; and low risk was a low-risk score in items 2, 3, 7, and 9.

For synthesis and assessment of heterogeneity, the data were imported into Metaprop version 14 (StataCorp software) to calculate appropriate pooled prevalence estimates; 95% CI, and subtotal estimates for subgroups according to study characteristics and various angulations of third molar, in line with the secondary objectives of the review.

The  $I^2$  metrics and p values were used to quantify heterogeneity across the studies. Tau<sup>2</sup> was used to estimate variance between studies, and z values to test for overall effect. The random effects model was used because of the differences in the studies, and the decision was based on statistical and clinical judgement.

Ethics approval was not necessary, as the study was a review of published papers.

## Results

The electronic searches initially yielded 81 records and the hand searches one. Two studies were excluded because only the abstracts were available. Table 2 shows those excluded,<sup>11,20–29</sup> and Fig. 1, the selection process.<sup>30</sup> The corresponding author of one of the published abstracts was contacted but did not reply. One study was only available electronically, and one, which had been withdrawn for unknown reasons, was consequently excluded. A total of 11 studies were included,<sup>4,9,13–15,18,31–35</sup> and prevalence subtotals of three prospective,<sup>4,9,13</sup> and three retrospective studies,<sup>18,31,33</sup> are presented.

The meta-analysis comprised three studies,<sup>4,9,13</sup> which also provided the information and data for subgroup analysis of different angulations of third molars and DSC. Descriptive information and characteristics of the studies are shown in Table 3.

### Results of narrative review

Studies from nine countries (11 452 second molars) showed a prevalence of DSC that ranged from 4.5% - 52%. Two were multicentre studies (three and seven sites).<sup>9,13</sup> The population

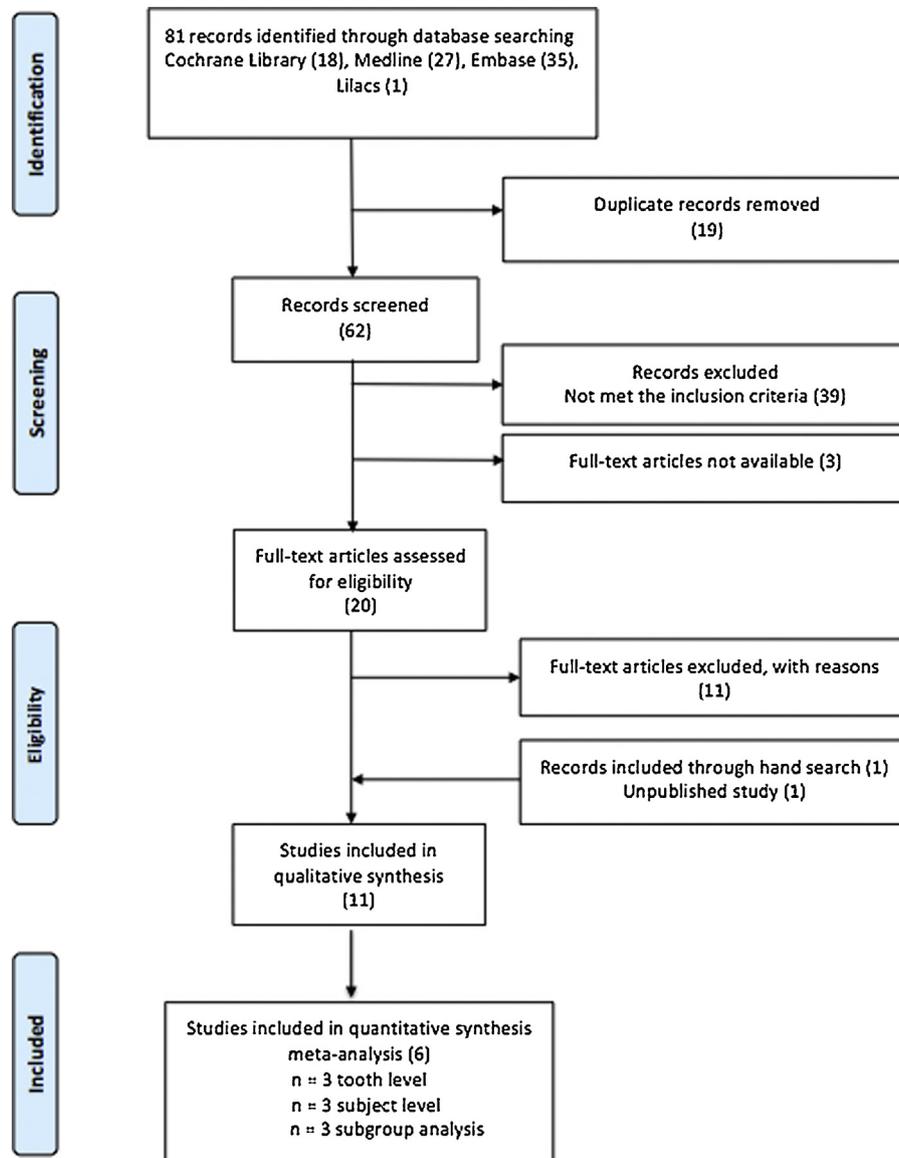


Fig. 1. PRISMA (Preferred Reporting Items for Systematic Review and Meta-analyses) flow diagram of the selection process.<sup>30</sup>

was assessed at a single time in each one, and in four<sup>4,9,13,35</sup> both the outcome assessment and data collection were done at a single time point. Seven studies<sup>14,15,18,31–34</sup> assessed this time point retrospectively through clinical notes and records.

Our secondary objective was to find out whether the estimate varied by factors such as population (general practice or hospital care), geographical location, demographics, time at which the study was conducted, general dental health, and characteristics of the third molars. All studies were conducted in hospitals. Six studies were from Asia,<sup>15,18,31–35</sup> three from Europe,<sup>4,9,13</sup> and two from South America.<sup>14,34</sup> The earliest included, by Knutsson et al, was published in 1996.<sup>13</sup> Since 2013, the prevalence of DSC reported in 10 further studies has been higher than that reported in 1996.

The studies reported the number and percentage of affected teeth or patients, or both, the corresponding sam-

ple size, and the diagnostic criteria/criterion used to detect DSC. Six studies used dental panoramic tomograms (DPT) as well as clinical examination,<sup>4,9,13,18,31,33</sup> and two of them also used preoperative or intraoperative examination after wisdom teeth had been removed.<sup>13,33</sup> In the remaining studies the methods varied, and caries were detected on radiographs (two studies used DPT,<sup>32,34</sup> one used periapical radiographs (PA)<sup>14</sup> and one a combination of DPT and periapical radiographs).<sup>35</sup> One used 3-dimensional scans and cone-beam computed tomography (CT).<sup>15</sup>

The overall age range was 14 – 89 years. The mean age, which was reported in seven studies,<sup>4,13–15,18,32,33</sup> ranged from 24 - 29 years. One study reported a median age of 28 years,<sup>9</sup> and another a mode of 27 years.<sup>4</sup> Three included a small number of patients under the age of 16.<sup>9,13,33</sup> The

Table 3

Descriptive information and characteristics of included prevalence studies (cross-sectional studies).

First author, year, and reference	Country/ Location	Continent	Care setting	Study design (single time point)	Age (years) Mean Range Median Mode	No. of molars and patients % male/female	DMFT Mean Range Median	Diagnostic criteria (method of diagnosis)	Prevalence of DSC No. of molars No. of patients % % angulation	Risk of bias
Knutsson 1996 <sup>13</sup>	Sweden	Europe	Hospital multi-centre (7)	Prospective	28 15-80 - -	666 molars 666 patients 47 M/53 F	-	CE DPT CE (intra-op)	29 molars, 29 patients 4.35% Mesial 55 Horizontal 17.2 Distal 13.8 Vertical 13.8	Moderate
Chu 2003 <sup>31</sup>	China Hong Kong	Asia	Hospital	Retrospective	- 17-89 - 20-29	3178 molars - -	-	CE DPT	234 molars - 7.37% -	Low
Polat 2008 <sup>32</sup>	Turkey Cumhuriyet	Asia	Hospital	Retrospective	25.91 18-60 - -	3050 molars 1914 patients 43.3 M/56.7 F	-	DPT	383 molars 241 patients 12.6% -	High
Chang 2009 <sup>33</sup>	Korea	Asia	Hospital	Retrospective	28.3 14-75 - -	883 molars 786 patients 39.3 M/60.7F	-	CE DPT CE (intra-op)	152 molars 135 patients 17.2% -	Moderate
Allen 2009 <sup>9</sup>	United Kingdom Surrey	Europe	Hospital multi-centre (3)	Prospective	- 14-88 28 -	776 molars 420 patients -	- 0-27 5	CE DPT	150 molars 113 patients 19.3% Mesial 74.7 Horizontal 8.7 Distal 3.3 Vertical 13.3	Moderate
Ozeç 2009 <sup>18</sup>	Turkey	Asia	-	Retrospective	25.2 18-49 - -	585 molars 485 patients -	-	CE DPT	117 molars 97 patients 20% -	High
Falci 2012 <sup>14</sup>	Brazil Mucuri	South America	Hospital	Retrospective	24.17 16-57 - -	246 molars - 28 M/72 F	-	PA	33 molars - 13.4% -	Moderate
Silva 2015 <sup>34</sup>	Brazil	South America	Hospital	Retrospective	- 18-35+ - -	157 molars 120 patients 36.3 M/63.7 F	-	DPT	40 molars 30.6 patients 25.5% -	Moderate
Kang 2016 <sup>15</sup>	China Shanghai	Asia	Hospital	Retrospective	29 16 – 59 - -	500 molars 469 patients 43.6 M/ 56.4 F	-	CBCT	260 molars 244 patients 52% -	Moderate
Yadav 2016 <sup>35</sup>	India Delhi	Asia	Hospital	Prospective	- 18-55 - -	1187 molars - 45.9 M / 54.1 F	-	DPT/PA	132 molars - 11.12% -	High
Toedtling 2016 <sup>4</sup>	United Kingdom Manchester	Europe	Hospital	Prospective	29 16-60 - 27	224 molars 210 patients 45.5 M/54.5 F	6 0-28	CE DPT	85 molars 80 patients 38% Mesial 70.6 Horizontal 15.2 Distal 2.4 Vertical 11.8	Low

CE- preoperative clinical examination, CE (intra-op)- intra-operative clinical examination, DPT- dental panoramic tomogram, PA-periapical radiograph, CBCT – Cone-beam computed tomography.

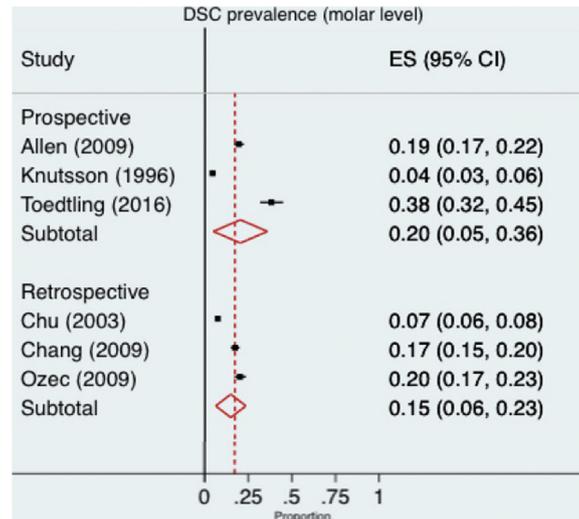


Fig. 2. Analyses of prevalence of distal surface caries (DSC) among molars in prospective and retrospective studies of patients who had clinical and radiological (DPT) examinations, and were referred from general practice to hospital care.

impact of this was taken into account and was integrated in the assessment of risk of bias (Table 3).

Eight studies reported the number of male and female participants<sup>4,13–15,32,33–35</sup> and all of them reported more women than men. A ratio of roughly 40:60 was common. Only two studies provided the DMFT index and DMFT range,<sup>4</sup> which varied widely (0–27<sup>9</sup> and 0–28,<sup>4</sup> respectively). Characteristics such as sex, DMFT index, and age, were either not fully reported or reported in a way that made direct comparison and analysis of specific subgroups impossible.

Our narrative review provided an insight. Synthesised data across studies, however, are largely subjective, and dissimilar estimates are likely to reflect a high degree of heterogeneity among the different groups. A meta-analysis can summarise the evidence objectively, and to facilitate this we excluded studies with dissimilar outcome measures. Five were excluded because they did not report clinical examination and DPT.<sup>14,15,32,34,35</sup>

#### Meta-analysis and subgroup analyses

Our meta-analysis included three studies<sup>4,9,13</sup> all of which provided samples for subgroup analyses. The prevalence subtotal among teeth was 20% (95% CI 5% to 36%)  $z=2.57$  ( $p=0.01$ ) in prospective,<sup>4,9,13</sup> and 15% (95% CI 6% to 23%)  $z=3.36$  ( $p=0.01$ ) in retrospective studies (Fig. 2).<sup>18,31,33</sup>

The pooled estimate according to the prospective studies,<sup>4,9,13</sup> and the prevalence among patients, are presented in Fig. 3. The heterogeneity across and between groups, as well as the significance within the subgroup, were:  $I^2=98.88\%$ ,  $\text{Tau}^2=0.03$ ,  $z=2.16$ , and  $p=0.03$ . In the subgroup analyses<sup>4,9,13</sup> the subtotals of the prevalence of DSC among third molars that were inclined mesially (36%, 95% CI 5% to 67%) and horizontally (22%, 95% CI 1% to 42%) ( $z=2.03$ ,  $p=0.04$ ) were significantly higher than those that were inclined distally (3%, 95% CI 1% to 5%) ( $z=3.20$ ,

$p=0.01$ ) or vertically (7%, 95% CI 1% to 13%) ( $z=2.38$ ,  $p=0.04$ ) (Fig. 4). The test of heterogeneity between subgroups was  $I^2=96.55\%$ .

DSC has been reported in three continents: Asia, Europe, and South America. Studies based in Europe suggest that up to 20% of third molar referrals and 23% of the patients referred for assessment have DSC in the second molar. Its prevalence in mesial and horizontal angulations was significantly higher than it was in distal and vertical angulations. Wide confidence intervals, however, suggest a lack of precision and the need for further studies, or inherent variation because of differences in the denominator populations.

#### Discussion

Previous studies have suggested that the retention of third molars can result in harm to the second molar, but the precise variables that increase the risk of DSC have not been adequately described. Our epidemiological data help us understand the extent of the problem, and our meta-analysis gives an insight into the epidemiology of DSC in the second molars of patients referred to hospital for assessments of third molars. All the studies were conducted in hospitals so there is no general population-based prevalence, which is an important limitation. However, our results show that DSC is a global phenomenon that is measured with an assortment of radiographic methods.

The meta-analysis showed a 23% pooled prevalence of DSC among patients (DSC therefore affects about one in four of those referred). The confidence intervals, however, were wide (44% to 2%), which suggests a lack of precision. We also detected considerable heterogeneity and suggest that this may be caused by several factors that are linked to differences in practice. To remove the uncertainty of the precision of the combined prevalence estimate, we did a random effects anal-

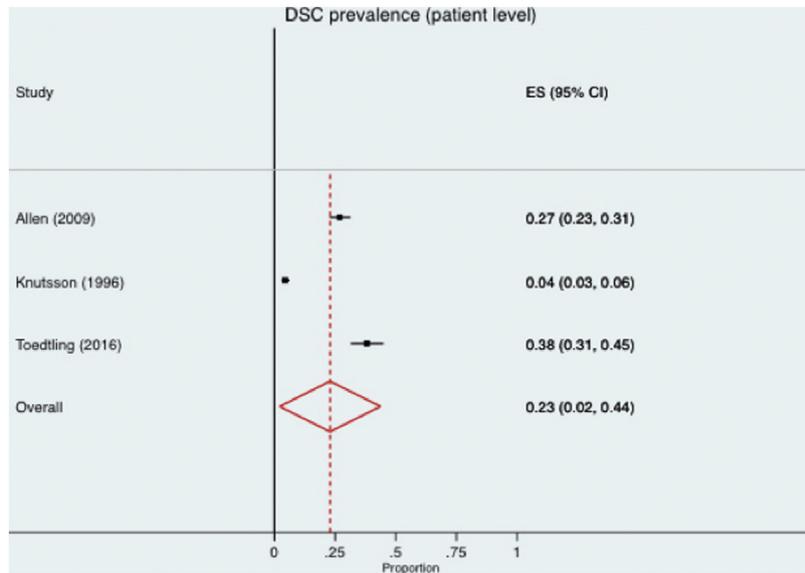


Fig. 3. Meta-analysis for prevalence of distal surface caries (DSC) among patients in prospective studies of patients who had clinical and radiological (DPT) examinations, and were referred from general practice to hospital care.

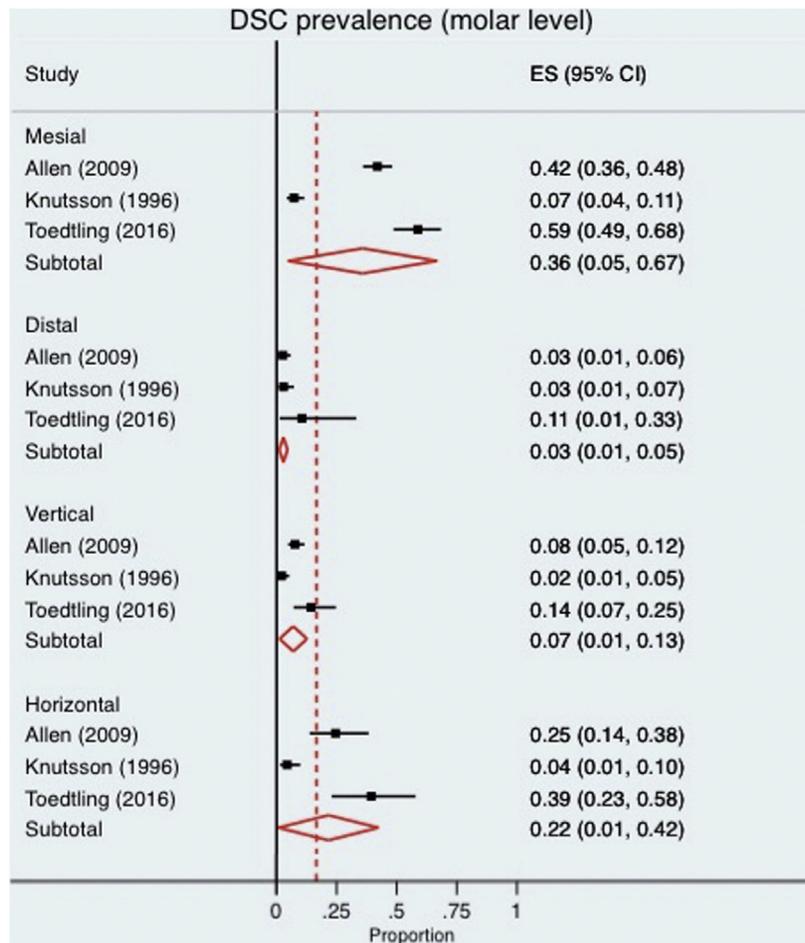


Fig. 4. Subgroup analysis for distal surface caries (DSC) among molars in various third molar angulations.

ysis. A subtotal of DSC among molars showed a prevalence of 20% in prospective, and 15% in retrospective, studies.

Testing for significance showed that the null hypothesis could be rejected, and we could accept that the prevalence of DSC was significantly higher in mesial (36%) and horizontal (22%) impactions than it was in vertical (7%) and distal (3%) impactions.

This overall rate is a product of current and previous clinical practice (removal of symptomatic and asymptomatic, or disease-free third molars) and therefore reflects both approaches to the management of retained teeth. Knuttson et al<sup>13</sup> reported the prevalence of DSC when third molars were removed prophylactically, whereas both the UK-based studies (Allen et al,<sup>9</sup> and Toedtling et al<sup>4</sup>) reported it when national guidelines stated that third molars should be removed only when associated with disease. This may explain the large difference in prevalence, and it supports current thinking on the retention of third molars and the harm this can cause.

The limitations of the meta-analysis include the considerable heterogeneity and, overall, the moderate quality of the studies. As described previously, the study sample comprised patients treated in hospital, so is not representative of the general population. Differences in the structure of publicly funded healthcare systems and insurance-based remuneration systems in different parts of the world, as well as variations in education and availability of resources, such as clinical guidance, may also have influenced our estimates. The remuneration systems in industrialised countries with national health services or insurance schemes, which range from fee-for-service to capitation payments, produce different incentives that influence attitudes to the retention and removal of third molars,<sup>36</sup> and rates of third molar agenesis and impaction differ.<sup>37</sup> The need and demand for their removal, which is thought to be associated with a lower prevalence of DSC, therefore varies widely.

The diagnostic criteria for DSC also varied, and some studies reported clinical examinations, which were correlated with a variety of radiographic images at various stages before and after the removal of third molars.

The European Commission radiation protection guidelines state that DPT is the radiographic investigation of choice for the assessment of third molars and, in most cases, this was used,<sup>38</sup> but as panoramic radiographs have poor sensitivity for the diagnosis of caries,<sup>38</sup> the prevalence of caries and progression may be underestimated.

Possible sources of bias in the meta-analysis were assessed with the risk of bias tool published by Hoy et al (Table 4).<sup>19</sup> We classified items 1, 4, 5, 6, 8, and 10 as less pertinent, items 3 and 9 as valuable, and items 2 and 7 as pertinent domains. Our reasoning was that all those in the less pertinent domain were already part of our exclusion criteria or had no direct application, whereas studies with a risk of bias in items in the valuable domain had direct implications for the analyses, and had the potential to introduce selection bias or reduce internal validity, which could overestimate or underestimate the results. Items in the pertinent domain were marked as most

Table 4  
Risk of bias of individual studies.

Studies	Risk of bias tool items*										
	1	2	3	4	5	6	7	8	9	10	11
Knuttson <sup>13</sup>	L	L	L	L	L	L	L	L	H	L	M
Chu <sup>31</sup>	H	L	L	L	L	L	L	L	L	L	L
Polat <sup>32</sup>	L	H	H	L	L	L	L	L	L	L	H
Chang <sup>33</sup>	H	L	L	L	L	L	L	L	H	L	M
Allen <sup>9</sup>	H	L	L	L	L	L	L	L	H	L	M
Ozeç <sup>18</sup>	H	H	H	L	L	L	L	L	L	L	H
Falci <sup>14</sup>	H	L	H	L	L	L	L	H	L	L	M
Silva <sup>34</sup>	H	L	L	L	L	L	L	L	H	L	M
Kang <sup>15</sup>	H	L	H	L	L	L	L	L	H	L	M
Yadav <sup>35</sup>	H	L	H	L	L	L	H	L	L	L	H
Toedtling <sup>4</sup>	H	L	L	L	L	L	L	L	L	L	L

L – low risk, M- moderate risk, H – high risk, \*2 and 7 – Pertinent items, 3 and 9 – Valuable items.

important and were therefore given the greatest weight. Studies with a risk of bias in this domain could affect the external validity and reliability of the meta-analysis, and reduce the extent to which the results could be extrapolated. We did not analyse the subgroups (DMFT, sex, and age) further, together or separately, because they were too small and too variable, and did not seem to reflect the purpose of the study.

We planned to assess possible publication bias with a funnel plot, but the number of studies was too low. We were also unable to do a sensitivity analysis, as only a small number of studies met our inclusion criteria. Despite this, we think that our selection process was rigorous. We addressed specific sources of bias and excluded studies of low quality and high risk of bias, so our results give the best possible estimates of the prevalence of DSC.

Indications for the removal of impacted wisdom teeth have been controversial for many years, and NICE has provided guidance specifically for England and Wales.<sup>10</sup> Several international guidance documents refer to the NICE first technology appraisal (TA1) recommendations (with an explanation of formal alignment),<sup>39–42</sup> but as NICE clearly stated that there was no research evidence to support them,<sup>10,11</sup> these documents also have a limited evidence base. Understandably, some nations (including the US) have challenged the NICE recommendations, and they have not been universally adopted.<sup>43–47</sup>

At present the cause of DSC remains unknown, but significant associations have been shown with mesially and horizontally impacted third molars.<sup>4,9</sup> Our subgroup analyses showed that when these were combined, the prevalence of DSC was almost six times higher than it was among a combination of distally and vertically inclined third molars. These findings agree with previous research and with the clinical suspicion and observation of practitioners over many years.<sup>6</sup>

Given the possible risks and costs of both DSC and prophylactic removal, international guidelines must be based on the results of high quality trials in different populations. Ultimately, to improve estimates of the prevalence of DSC and to find answers to our secondary objectives, larger well-reported

observational studies are needed, but research funding might be better spent on interventional studies that show how best to manage impacted third molars and their consequences.

### Conflict of interest

We have no conflicts of interest.

### Ethics statement/confirmation of patients' permission

Ethics approval not required as this manuscript is a systematic review of published papers. Patients' permission was not necessary.

### Acknowledgement

The authors thank Dr. Ingrid Zollinger from the University of Manchester Library Systematic Review Team for her advice on the search strategy.

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