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ROBERTA ALMEIDA MENDES

RAIZ ADICIONAL EM MOLARES INFERIORES: UMA REVISÃO SISTEMÁTICA E META-ANÁLISE ATRAVÉS DE ESTUDOS DE TOMOGRAFIA COMPUTADORIZADA DE FEIXE CÔNICO, DEMONSTRANDO A PREVALÊNCIA DE ACORDO COM A REGIÃO GEOGRÁFICA E FATORES PREDITORES

PORTO ALEGRE, 2022

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Orientador (a): Profª. Drª. Fabiana Soares Grecca

Linha de pesquisa: Epidemiologia, Etiopatogenia e Repercussão das Doenças da Cavidade Bucal e Estruturas Anexas.

Porto Alegre 2022

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“Os sonhos não determinam o lugar que você vai estar, mas produzem a força necessária para o tirar do lugar em que está”.

(Augusto Cury)

RESUMO

Introdução: A avaliação da morfologia dentária pré-operatória por meio da tomografia computadorizada de feixe cônico (TCFC) tornou-se um importante auxílio ao planejamento endodôntico. No entanto, a disponibilidade e as indicações para seu uso ainda são limitadas. Estudos avaliando a prevalência e distribuição geográfica de morfologias endodônticas atípicas são necessários.

Objetivos: Esta revisão sistemática e meta-análise de estudos transversais de CBCT avaliou a prevalência de raiz adicional em molares inferiores permanentes.

Métodos: Esta revisão é relatada de acordo com a lista de verificação PRISMA. Os artigos em inglês, português e espanhol foram selecionados de acordo com critérios de inclusão/exclusão pré-definidos e avaliados por meio da ferramenta de avaliação crítica do Joanna Briggs Institute. A busca eletrônica foi realizada nas bases de dados PubMed, ScienceDirect, LILACS, Cochrane Collaboration, Embase, Web of Science e Scopus, bem como na literatura cinza (Google Scholar e OpenGrey). A meta-análise foi realizada com o software Review Manager usando o método Mantel-Haenszel. O teste de Egger e os gráficos de funil foram utilizados para avaliar o viés de publicação dos dados analisados ($p < 0,05$).

Resultados: Quarenta e dois estudos foram selecionados na síntese qualitativa e 39 estudos foram incluídos na meta-análise. O risco de viés de todos os estudos incluídos foi baixo (~71%). ados coletados de 21 países diferentes relataram 25.817 e 12.716 primeiros e segundos molares inferiores, respectivamente. Raiz adicional foi mais comumente encontrada em primeiros molares e em países asiáticos, principalmente do Leste Asiático. A raiz entomolar (RE) foi mais prevalente que a raiz paramolar (RP). Os homens mostraram maior probabilidade de ter raízes adicionais do que as mulheres. No entanto, este efeito foi significativo apenas para os primeiros molares.

Discussão: Os resultados aqui demonstrados contribuem para a prática clínica, pois alertam para a prevalência e fatores predisponentes de morfologia atípica em molares inferiores. Especialmente em primeiros molares, homens e pessoas de etnia asiática, os clínicos devem realizar uma busca atenta de raízes adicionais e a TCFC deve ser indicada para o planejamento do tratamento endodôntico. A raiz adicional "não especificada" foi incluída como subgrupo para evitar uma possível prevalência de subestimação, uma vez que alguns estudos não definiram exatamente a localização da raiz adicional, dificultando este estudo.

Conclusões: A prevalência global da raiz adicional em molares inferiores permanentes foi de 10,3%. Os países do Leste Asiático apresentaram as maiores prevalências, com valores variando de 19 a 25,4%. Os primeiros molares foram mais comumente afetados do que os segundos molares. O RE foi mais prevalente quando comparado ao RP.

Palavras-chave: Endodontia. Prevalência. Radix entomolaris. Radix paramolaris. Raiz adicional. Tomografia computadorizadade feixe cônico.

ABSTRACT

Background: Assessment of preoperative morphology through cone-beam computed tomography (CBCT) has become an important aid to endodontic planning. However, availability and indications for its use are still limited. Studies evaluating the prevalence and geographic distribution of atypical endodontic morphologies are warranted.

Objectives: This systematic review and meta-analysis of CBCT cross-sectional studies assessed the prevalence of additional roots in permanent mandibular molars.

Methods: This review is reported according to the PRISMA checklist. English, Portuguese, and Spanish articles were selected according to predefined inclusion/exclusion criteria and evaluated using the Joanna Briggs Institute Critical Appraisal tool. The electronic search was conducted in PubMed, ScienceDirect, LILACS, Cochrane Collaboration, Embase, Web of Science, and Scopus databases, as well as in the grey literature (Google Scholar and OpenGrey). The meta-analysis was conducted with Review Manager Software using the Mantel–Haenszel method. Egger's test and funnel plots were used to assess publication bias ($p < 0.05$).

Results: Forty-two studies were selected for qualitative synthesis, 39 of them included in the meta-analysis. Risk of bias was mostly low (~71%). Data gathered from 21 different countries reported 25 817 and 12 716 mandibular first and second molars, respectively. Additional roots were more commonly found in first molars and in Asian countries, mainly from East Asia. Radix entomolaris (RE) was more prevalent than radix paramolaris (RP). Men showed a greater likelihood of having additional roots. However, this effect was only significant for first molars.

Discussion: The results demonstrated herein contribute to clinical practice, alertingto the prevalence and predisposing factors of atypical morphology in mandibular molars. Especially in first molars, men, and Asians, clinicians should perform an attentive search for additional roots and CBCT should be indicated for treatment planning. The additional root subgroup 'non-specified' was included to avoid possible underestimation of prevalence since some studies did not define exactly the location of the additional root, making this study difficult.

Conclusions: The global prevalence of an additional root in permanent mandibular molars was 10.3%; prevalence was highest in East Asian countries (19% to 25.4%). First molars were more commonly affected than second molars. RE was more prevalent when compared to RP.

Keywords: Additional Root. Cone-Beam Computed Tomography. Endodontics. Prevalence. Radix Entomolaris. Radix Paramolaris.

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1 ANTECEDENTES E JUSTIFICATIVA

O tratamento endodôntico tem por objetivo a limpeza e modelagem do sistema de canais radiculares através do preparo químico-mecânico, resultando na remoção de conteúdo séptico (Zheng et al., 2009) a níveis compatíveis com a cura e cicatrização periapical (Vera et al., 2012; Vianna et al., 2006), bem como na obturação tridimensional (Chen et al., 2009; de Moor et al., 2004; Sperber & Moreau, 1998; Vertucci & Gainesville, 1884). Entretanto, para o sucesso do tratamento, é necessário o conhecimento da anatomia dentária, localização das raízes e canais radiculares (Baruwa et al., 2020; Costa et al., 2019)e suas variações (Cantatore et al., 2006; de Souza-Freitas et al., 1971; Huang et al., 2010; Wang et al., 2010).

Canais radiculares não tratados possuem de 4,4 a 6,25 mais chances de desenvolver periodontite apical (Baruwa et al., 2020; Costa et al., 2019). Ao avaliar 337 dentes tratados endodonticamente, Hoen e colaboradores (2002) observaram ausência de tratamento de um dos canais radiculares em 42% dos casos. Outros estudos mostraram que o esquecimento de um dos canais estava presente em 12% dos casos em geral (Baruwa et al., 2020; Costa et al., 2019), sendo 11,2% dos casos em primeiros molares inferiores e 9,5% nos segundos molares inferiores (Baruwa et al., 2020). Dessa forma, compreende-se que a necessidade do retratamento endodôntico está, muitas vezes, relacionada à incapacidade do profissional em reconhecer a anatomia e a presença de canais ou raízes adicionais (Chen et al., 2009).

Os dentes mais comumente tratados endodonticamente são os primeiros molares inferiores permanentes, relatados em 17,4% dos casos por Zaatar et al., e 18,8% dos casos por Serene et al. (Serene & Spolsky, 1981; Zaatar et al., 1997). Esse grupo dentário é o primeiro a erupcionar na cavidade oral, por volta dos 6 anos de idade, ainda na dentição mista (Pham & Le, 2019). Ou seja, apresenta um papel essencial na cavidade oral, porém sofre um contínuo processo de desmineralização ao longo da vida, muitas vezes, sem prevenção e tratamento (Deng et al., 2018), sendo então, mais propenso à cárie e consequentemente à necessidade de tratamento endodôntico (Madani et al., 2017; Touré et al., 2011; X. Zhang et al., 2015). Ainda, são os dentes mais comumente extraídos (44,6%) e dentre as suas causas está na impossibilidade de restauração devido a extensa lesão cariosa (61,4%), seguido de falhas endodônticas, 12,2% segundo Zadik et al. em 2008 e 19,3% segundo Hosseini et al. em 2020.

Apesar de os molares inferiores apresentarem geralmente duas raízes, sendo uma distal e outra mesial (Loh, 1990), alguns apresentam uma raiz adicional como variação anatômica (Jang et al., 2013; Senan et al., 2020). Esse diagnóstico pré-operatório evita complicações e falhas na terapia endodôntica (Patil et al., 2018). Essa raiz suplementar normalmente está presente lingualmente a raiz distal (de Moor et al., 2004; de Souza-Freitas et al., 1971; Tu et al., 2009) e está relacionada fortemente com alguns grupos étnicos específicos (de Pablo et al., 2010; Duman et al., 2020; Miloglu et al., 2013).

A terceira raiz localizada distolingualmente em molares inferiores foi descrita pela primeira vez por Carabelli em 1844 e foi denominada radix entomolaris (RE) (Senan et al., 2020). Posteriormente, outra raiz adicional foi detectada mesiovestibularmente, mencionada na literatura por Bolk em 1914, e chamada de radix paramolaris (RP) (Carlsen et al., 1991).

A etiologia da radix é incerta, porém pode estar atribuída a fatores externos durante a odontogênese ou fatores genéticos (Agarwal et al., 2015; Alenezi et al., 2020; Calberson et al., 2007). A literatura mostra sua relação com as diferenças genéticas no contexto racial (Kantilieraki et al., 2019; Song et al., 2010). A maior prevalência da terceira raiz é observada nos asiáticos, mongóis e esquimós (de Pablo et al., 2010; Tu et al., 2007). Em 1974, Curzon descreveu a presença da terceira raiz em primeiros molares inferiores como uma característica normal entre os esquimós e não uma anormalidade (Curzon, 1974). Apesar da a frequência de casos serem menores na população asiática, ainda são mais comuns comparados à população caucasiana (Kantilieraki et al., 2019). Uma prevalência de RE máxima de 3% foi encontrada na população africana e inferior a 5% na população eurasiática e indiana, diferente da população mongoloide (chineses, esquimós e indígenas americanos) com prevalência entre 5% a >30% (Agarwal et al., 2015). A bilateralidade de casos de RE foi relatada em cerca de 60% dos casos (Sarangi et al., 2014). A prevalência de RP é considerada rara e menos comum quando comparada a RE (Calberson et al., 2007).

A prevalência de RE é maior em primeiros molares inferiores quando comparada aos segundos molares inferiores (Duman et al., 2020). A RE é normalmente menor do que a raiz distovestibular (Song et al., 2010) ou a RP, e frequentemente apresenta uma curvatura (de Moor et al., 2004; Rahimi et al., 2017; Tu et al., 2009). Sua separação da raiz distal principal se dá na porção cervical. Já a RP apresenta-se geralmente como uma raiz reta e de tamanho semelhante à raiz mesial principal, e sua separação normalmente é no terço apical com a raiz mesial (Shemesh et al., 2015).

Para o sucesso do tratamento endodôntico é importante além de conhecer a anatomia, ter o domínio da morfologia e localização de acesso ao canal radicular dessa terceira raiz adicional. A entrada do canal da RE está localizada de disto para mesiolingualmente a partir do canal principal ou canais da raiz distal (Abella et al., 2011; Calberson et al., 2007) A cavidade de acesso é modificada da forma triangular para retangular ou trapezoidal (Abella et al., 2011; Calberson et al., 2007; Chen et al., 2009; de Moor et al., 2004). Uma cavidade de acesso inapropriada pode acarretar na não localização do quarto canal (Sperber & Moreau, 1998). Nos casos de difícil visualização da entrada do canal, é possível inspecionar uma linha escura no soalho da câmara pulpar indicando a localização do canal da raiz adicional (Abella et al., 2011; Calberson et al., 2007; de Moor et al., 2004). Uma cúspide extra ou mais proeminente na oclusodistal ou distolingual, em combinação com uma proeminência cervical pode indicar a presença de uma raiz adicional (Calberson et al., 2007). Entretanto, Sperber e Moreau relatam que um número maior de cúspides no primeiro molar inferior não necessariamente está relacionado a uma raiz adicional (Sperber & Moreau, 1998).

A análise da morfologia dentária pré-operatória através de exames clínicos e de imagens é fundamental para o sucesso do tratamento endodôntico (Celikten et al., 2016). A radiografia intrabucal é o método de escolha para o diagnóstico e durante todas as etapas do tratamento endodôntico (Durack & Patel, 2012; Omer et al., 2004; Wu et al., 2006; Yılmaz et al., 2016). Entretanto, esse método de exame por imagem dificulta a identificação da raiz adicional em molares inferiores, principalmente quando essa raiz está sobreposta à outra (Calberson et al., 2007; Loh, 1990; Omer et al., 2004; Zhang et al., 2011). Nesses casos, o indicado seria realizar a dissociação radiográfica, com tomadas radiográficas em diferentes angulações, uma ortorradial e outra com ângulo de 30^0 para distal ou mesial (Abella et al., 2011; de Moor et al., 2004). Entretanto, essa técnica pode causar alguma distorção (Neelakantan et al., 2010), ou ainda não garantir a identificação da anatomia (Abella et al., 2011). Por outro lado, exames por imagens em três dimensões (3D) são capazes de eliminar sobreposições e facilitar o diagnóstico de variações de anatomia (Cotton et al., 2007).

A tomografia computadorizada de feixe cônico foi introduzida na Endodontia em 1990 (Tachibana & Matstjmoto, 1990). O seu desenvolvimento teve como objetivo suprir as limitações das radiografias convencionais (Durack & Patel, 2012) através de imagens em três planos distintos, sendo eles coronais, sagitais e axiais (Kantilieraki et al., 2019; Poonam & Hans, 2017). Esse método de imagem possui uma melhor acurácia no diagnóstico, se comparado às radiografias intrabucais (H.-H. Kim et al., 2018), detectando variações anatômicas tanto externas, quanto internas e suas complexidades (Nair & Nair, 2007; Silva et al., 2013). Em um estudo comparando a acurácia de diferentes métodos de diagnóstico por imagens na detecção de canais radiculares em dentes extraídos, a TCFC apresentou melhores resultados, apresentando imprecisão no diagnóstico de somente 0,29% dos canais radiculares, enquanto o diagnóstico com a radiografia digital foi impreciso em 23,8% (Neelakantan et al., 2010). Dessa forma, os desafios de uma variação anatômica, como a radix, podem ser minimizados com o auxílio de uma ferramenta de imagem 3D (Hosseini et al., 2020), contribuindo para a localização exata da raiz supranumerária e suas curvaturas, contribuindo para o sucesso do tratamento (Al-Alawi et al., 2020).

A TCFC não é considerada um método padrão para diagnóstico em endodontia, porém é indicada em casos onde a radiografia intrabucal fornece informações inadequadas ou incertas para detecção da anatomia e planejamento do tratamento, principalmente em casos de dentes mutirradiculares (Sedentexct, 2011).

Desde a introdução da TCFC na endodontia, estudos utilizando essa ferramenta têm sido realizados para avaliação da prevalência e localização da raiz supranumerária em molares inferiores permanentes (Tu et al., 2009). Porém, até o momento, não há um estudo de revisão sistemática e meta-análise que contemple a prevalência de primeiros e segundos molares inferiores, de acordo com o tipo de raiz adicional, o sexo e com a localização geográfica mundial. Diante disso, compreende-se a necessidade da síntese desses resultados e a avaliação crítica da literatura disponível. Dessa forma, o objetivo da presente revisão sistemática é avaliar a prevalência de raiz adicional em molares inferiores permanentes.

2 OBJETIVOS

Objetivo geral

Avaliar a prevalência de raiz adicional em primeiros e segundos molares permanentes inferiores, através de estudos transversais que avaliaram dentes *in vivo* por tomografia computadorizada de feixe cônico, de acordo com o sexo, tipo de raiz adicional e localização geográfica.

Objetivos Específicos

Avaliar a qualidade metodológica dos estudos primários incluídos através da ferramenta JBI Critical Appraisal.

Avaliar o risco de viés dos estudos primários incluídos através da ferramenta JBI Critical Appraisal.

Sintetizar estatisticamente os dados obtidos dos estudos primários através da ferramenta Review Manager.

3 ARTIGO CIENTÍFICO

Additional roots in mandibular molars: a systematic review and meta-analysis of CBCT studies showing prevalence according to geographic region and predictor factors

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Running Title: Prevalence of Additional Root.

Keywords: Additional Root; Cone-Beam Computed Tomography; Endodontics; Mandibular Molar; Prevalence; Radix Entomolaris; Radix Paramolaris; Root Canal.

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Abstract

Background: Assessment of preoperative morphology through cone-beam computed tomography (CBCT) has become an important aid to endodontic planning. However, availability and indications for its use are still limited. Studies evaluating the prevalence and geographic distribution of atypical endodontic morphologies are warranted.
Objectives: This systematic review and meta-analysis of CBCT cross-sectional studies assessed the prevalence of additional roots in permanent mandibular molars.
Methods: This review is reported according to the PRISMA checklist. English, Portuguese, and Spanish articles were selected according to predefined inclusion/exclusion criteria and evaluated using the Joanna Briggs Institute Critical Appraisal tool. The electronic search was conducted in PubMed, ScienceDirect, LILACS, Cochrane Collaboration, Embase, Web of Science, and Scopus databases, as well as in the grey literature (Google Scholar and OpenGrey). The meta-analysis was conducted with Review Manager Software using the Mantel–Haenszel method. Egger's test and funnel plots were used to assess publication bias ($p < 0.05$).
Results: Forty-two studies were selected for qualitative synthesis, 39 of them included in the meta-analysis. Risk of bias was mostly low (~71%). Data gathered from 21 different countries reported 25 817 and 12 716 mandibular first and second molars, respectively. Additional roots were more commonly found in first molars and in Asian countries, mainly from East Asia. Radix entomolaris (RE) was more prevalent than radix paramolaris (RP). Men showed a greater likelihood of having additional roots. However, this effect was only significant for first molars.
Discussion: The results demonstrated herein contribute to clinical practice, alertingto the prevalence and predisposing factors of atypical morphology in mandibular molars. Especially in first molars, men, and Asians, clinicians should perform an attentive search for additional roots and CBCT should be indicated for treatment planning. The additional root subgroup 'non-specified' was included to avoid possible underestimation of prevalence since some studies did not define exactly the location of the additional root, making this study difficult.
Conclusions: The global prevalence of an additional root in permanent mandibular molars was 10.3%; prevalence was highest in East Asian countries (19% to 25.4%). First molars were more commonly affected than second molars. RE was more prevalent when compared to RP.

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Introduction

The success of endodontic treatment relies on adequate cleaning and shaping of the root canal system (i.e., chemical mechanical preparation) (Zheng *et al.* 2009). In this regard, knowledge of anatomical characteristics and their inherent variations typically found among the worldwide population is of paramount importance to achieve root canal cleaning (Souza-Freitas *et al.* 1971, Cantatore *et al.* 2006, de Huang *et al.* 2010, Wang *et al.* 2010).

Mandibular first molars represent the most frequently endodontically treated teeth, accounting for 17.4% (Serene & Spolsky 1981) to 18.8% of reported cases (Zaatar *et al.* 1997). In addition, they are the teeth with the highest rate of extraction (44.6%), mostly due to endodontic failures (12.2%) which may be associated with untreated root canals (Zadik *et al.* 2008). Remarkably, the identification of a missed root canal was observed in 12% (Costa *et al.* 2019, Baruwa *et al.* 2020) to 42% of cases (Hoen & Pink 2002), mandibular first molars being more frequently affected (11.2%) than mandibular second molars (9.5%) (Baruwa *et al.* 2020). Endodontically treated teeth with missed canals are 4.4 to 6.3 times more likely to develop apical periodontitis (Costa *et al.* 2019, Baruwa *et al.* 2020).

Mandibular molars usually have two roots, one distal and one mesial (Loh 1990). However, the presence of an additional root can occur, and it is considered an anatomical variation (Jang *et al.* 2013, Senan *et al.* 2020). Preoperative diagnosis of these variations prevents complications and failures in endodontic therapy (Patil *et al.* 2018). This supplementary root is usually present lingually to the distal root (de Souza-Freitas *et al.* 1971, de Moor *et al.* 2004, Tu *et al.* 2009, Senan *et al.* 2020) and it was first described by Carabelli in 1844; this variation is referred as radix entomolaris (RE). Later, another possibility of an additional root was detected vestibularly to the mesial root and described by Bolk (1914); this additional root was called radix paramolaris (RP) (Carlsen *et al.* 1991). The aetiology of the additional root is uncertain, although it can be related to external factors during odontogenesis or genetic factors (Calberson *et al.* 2007, Agarwal *et al.* 2015, Alenezi *et al.* 2020) and it is strongly related to some specific ethnic groups (de Pablo *et al.* 2010, Miloglu *et al.* 2013, Duman *et al.* 2020).

The analysis of dental morphology preoperatively through clinical and imaging exams is essential to the success of endodontic treatment (Celikten *et al.* 2016). Intraoral radiography is the method of choice for diagnosis and overall treatment (Omer *et al.* 2004, Wu *et al.* 2006, Durack & Patel 2012, Yılmaz *et al.* 2016). However, this imaging method makes it difficult to identify the additional root in mandibular molars (Loh 1990, Omer *et al.* 2004, Calberson *et al.*

2007, Zhang *et al.* 2011). Cone-beam computed tomography (CBCT) can overcome the limitations of conventional radiographs (Durack & Patel 2012) through images in three different planes, namely the coronal, sagittal, and axial planes (Poonam & Hans 2017, Kantilieraki *et al.* 2019). In this way, the challenges derived from a radix anatomical variation can be minimized (Hosseini *et al.* 2020), contributing to the success of the treatment (Al-Alawi *et al.* 2020).

Although the assessment of preoperative morphology through CBCT has become an important aid to endodontic planning, availability and indications for its use are still limited (Durack & Patel 2012), and studies demonstrating the prevalence and predictor factors of atypical morphologies are needed to make clinicians aware of its possible occurrence (Martins *et al.* 2019). Since the introduction of CBCT in endodontics, several studies using this tool have been carried out to assess the prevalence of a supernumerary root in mandibular permanent molars. However, no systematic review and meta-analysis has been conducted to address the prevalence of an additional root in mandibular molars, according to the type of tooth (first and second mandibular molar), sex, and worldwide geographic location. In view of this, the need to synthesize these results and critically evaluate the available literature is understood. The research question framed for the systematic review was: What is the prevalence os additional root in permanent mandibular molars through cross-sectional studies that used CBCT?

Methods

Protocol and registration

This systematic review and meta-analysis protocol is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (Page *et al.* 2021). It was registered in the International Prospective Register of Ongoing Systematic Reviews (PROSPERO) under registration number CRD42020209381 entitled ‘Prevalence of additional root in permanent mandibular molars using cone-beam computed tomography - a systematic review and meta-analysis’. The clinical question was formulated and organized using the Population (first and second mandibular molars), Intervention (CBCT), Comparison (two roots), Outcome (additional root), and Study (cross-sectional study) (PICOS) strategy.

Eligibility criteria, information sources, search strategy, and study selection

An electronic search was undertaken with no date restriction for studies published up to 5th November 2021. Nine electronic databases were accessed (PubMed, ScienceDirect, LILACS, Cochrane Collaboration, Embase, Web of Science, Scopus) and grey literature

(Google Scholar and the OpenGrey repository) for cross-sectional studies that reported the occurrence of additional roots using CBCT images *in vivo*.

The search strategies were carried out using specific terms and filters (Table S1). After identification in the database, the studies were imported into EndNote Web software® (https://www.myendnoteweb.com), and duplicates were removed.

At first, titles and abstracts were assessed by two independent reviewers (RAM and LSP) and characterized as relevant or irrelevant in agreement with predefined inclusion and exclusion criteria (Table S2). Afterward, the full texts selected were evaluated by the same two reviewers according to the mentioned criteria. Disagreements between the reviewers were solved by discussion and a consensus was defined by another senior investigator (FSG). Reference lists of the studies selected for full-text reading were screened manually. Before inclusion, articles were submitted to a critical appraisal of the level of their scientific merit, using the Joanna Briggs Institute (JBI) Critical Appraisal tool (Table S3). Studies with a JBI Critical Appraisal score equal or greater than 50% were included. An attempt was made to contact the authors of five studies, but without response.

Scientific merit assessment

The quality assessment of the selected studies followed the checklist for prevalence studies from the JBI Critical Appraisal tool for use in cross-sectional studies(Munn *et al.* 2015). Two evaluators (RAM, LSP) independently assessed the eligible studies and evaluated them through the JBI checklist that is composed of nine questions that were scored as yes, no, unclear, or not applicable (Table S3). Items 5 and 9 of the JBI checklist were excluded from the analysis because they were not applicable and item 6 was excluded because of the predefined CBCT technique (Martins *et al.* 2019, Magnucki & Mietling 2021). The assessment discrepancies were discussed, and a consensus was defined by another senior investigator (FSG). The final score of each study applied to the JBI questions was calculated based on the percentage of positive answers (yes) only. Then, the risk of bias (RoB) of each study was categorized according to the final score as ‘high’ (score equal to or lower than 49%, which led to exclusion of the article), ‘moderate’ (score ranging from 50% to 69%), or ‘low’ (score higher than 70%) (Martins *et al.* 2019).

Data extraction

The first reviewer (RAM) extracted data from the included studies into a standardized data spreadsheet in Microsoft Office Excel® 2016 (Microsoft Corporation, Redmond, WA, USA), and the second reviewer (LSP) double-checked the extracted data. Disagreements between the reviewers were solved by discussion, and a consensus was established by a senior investigator (FSG). Data extracted from the studies included the following: article identification (authors, year of publication, title, country), participants' characteristics (average age, sex, date, number of subjects, number of teeth, number of first molars, number of second molars), methods (CBCT device, voxel size), results (prevalence of additional root according to sex (males/females) and additional root location), and type of tooth (first molar/second molar).

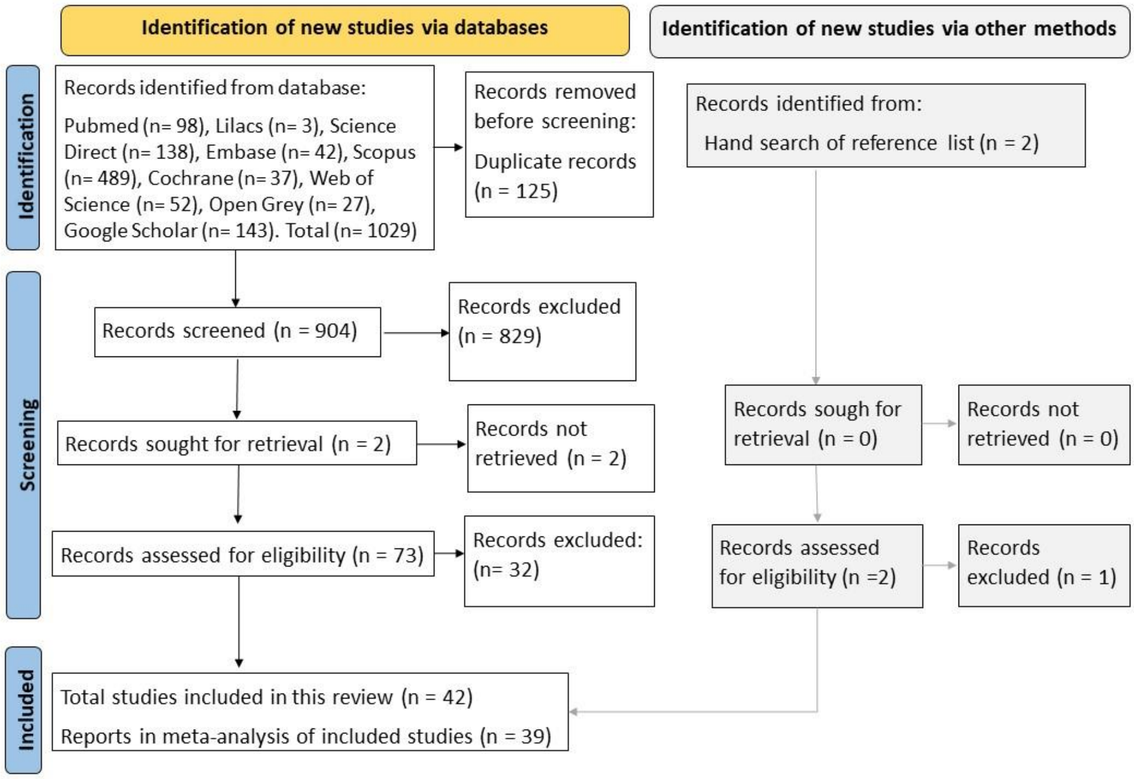
Statistical analysis

The occurrence of an additional root in mandibular molars was investigated as the main outcome in this review, and meta-analysis was conducted with Review Manager Software version 3.5.3 (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark) using the Mantel–Haenszel method, a random-effect model, and having an odds ratio (OR) estimate with 95% confidence interval (95% CI). One global analysis was performed comparing first and second molars. Also, subgroup analyses were applied by grouping studies according to sex (male or female), tooth (first or second molar), and type of radix (entomolaris, paramolaris, or non-specified) variables. Statistical heterogeneity of the treatment effect among studies was assessed quantitatively using the I^2 statistic (Higgins & Thompson 2002). The publication bias across the studies was assessed using Egger's test, and contour-enhanced funnel plots were used for visual analysis. A p-value < 0.05 was considered statistically significant.

Results

Initial screening revealed 1 029 studies. After discarding duplicates, 904 articles were eligible for title reading, from which 75 were selected for abstract analysis. Seventy-five papers were eligible for full-text reading, two of which were not retrieved. A manual search of the reference list found two studies. After full-textual assessment of 75 papers (73 via database; 2 via manual search), 33 did not meet the inclusion criteria, being excluded (exclusions are summarized in Supplemental Table S4). Finally, 42 studies (41 via database; 1 via manual search) were included in the review. Thirty-nine studies were suitable for meta-analysis, three (Kim *et al.* 2017, Poonam & Hans 2017, Hosseini *et al.* 2020) being excluded because they did not assess sex and/or tooth for statistical analysis (Figure 1).

Figure 1. PRISMA flow diagram of screening and selection processes.



Descriptive analysis

The included studies reported data of 25 817 mandibular first molars and 12 716 mandibular second molars, from at least 18 767 subjects (8 700 males and 9 905 females); two studies did not report the total number of subjects investigated and did not report the number of males and females (Hosseini *et al.* 2020, Jamshidi *et al.* 2021). The analysed data were derived from 21 different countries. The average age of subjects was 32.23 years, calculated based on 29 studies that reported this information.

Table 1 summarizes the studies' characteristics, patient demographics, and total number of teeth per subject. Table 2 shows the prevalence (number of teeth and percentage) of an additional root (overall and distributed by sex), and classification according to the location of the additional root (when the study reported it) or only as a third or fourth additional root (when there was no localization specified).

Table 1 Summary of characteristics of included studies.

	Author, year	Country	Date of extration	CBCT device	Voxel size (mm)	Number subjects	Average age (min-max)	Men/ women (subject)	Number of teeth (first and second molar)
1	(Al-Alawi *et al.*, 2020)	Saudi Arabia	2014-2018	Promax 3D Max (Planmeca, Helsinki, Finland), Galileos Comfort (Sirona Dental Systems GmbH, Bensheim, Germany), CS9300 (Carestream Dental LLC, Atlanta, GA, USA)	0.2-0.4mm, 0.2-0.4mm, 0.9mm	450	NA (16-70)	252/198	741
2	(Alenezi *et al.*, 2020)	Saudi Arabia	2020	Promax 3D Max (Planmeca, Helsinki, Finland)	0.2-0.6mm	400	37.12 (16-53)	209/191	400
3	(Alvarez & Alvarado, 2018)	Peru	2012-2014	NA	NA	176	NA	73/101	174
4	(Celikten *et al.*, 2016)	Cyprus	2012-2015	NewTom 3G (NewTom 3G: Quantative Radiology s.r.l., Verona, Italy)	0.3mm	272	NA (16-80)	NA*	805
5	(Demirbuga *et al.*, 2013)	Turkey	2011-2012	NewTom 5G (Newtom 5G, QR, Verona, Italy)	NA	605	35.7 (15-78)	268/337	1748
6	(Duman *et al.*, 2020)	Turkey	2011-2018	NewTom G5 (VERONA, ITALY)	0.125mm	850	25.68 (15-49)	375/475	2800
7	(Gastelú, 2019)	Peru	2013-2017	Promax 3D (Planmeca)	0.2mm	227	32.27	114/113	384
8	(Gomez *et al.*, 2021)	Venezuela	2014-2017	Kodak 9000 3D unit (Carestream Dental, Atlanta, GA, USA)	0.076mm	161	NA	NA*	190
9	(Hiran-us *et al.*, 2021)	Thailand	2014-2016	3D AccuitomoTomograph (Morita, Kyoto, Japan)	0.08-0.25mm	248	45 (15-79)	111/137	567
10	(Hosseini *et al.*, 2020)	Iran	NA	Newtom 5G (Newtom,Verona,Italy)	0.075mm	NA	NA	NA	200
11	(Huang *et al.*, 2010)	Taiwan	2006-2009	CBCT (i-CAT; Imaging Sciences International, Hatfield, PA, USA)	0.4mm	151	NA (10-90)	76/75	237
12	(Jamshidi *et al.*, 2021)	Iran	NA	ProMax 3D CBCT unit (Planmeca Oy, Helsinki, Finland)	NA	NA	37	NA	327
13	(Jang *et al.*, 2013)	Korea	2008-2011	Implagraphy System (Vatech, Seoul, Korea)	0.2mm	472	45.8 (8-88)	247/225	780

14	(Kantilieraki *et al.*, 2019)	Greece	2015-2017	NewTom Vgi Evo (NewTom, Verona, Italy) and Scanora 3D (Soredex Co., Tuusula, Finland)	0.1mm	1002	37 (18-65)	410/592	1002
15	(Kim H *et al.*, 2018)	Korea	2012-2013	CB Mercuray (Hitachi Medical Corp., Tokyo)	0.2mm	432	24 (11-62)	223/209	864
16	(Kim & Yang, 2012)	Korea	2009-2010	i-CAT; Imaging Sciences International, Hatfield, PA)	0.4mm	1400	28.5	704/969	2800
17	(Kim S *et al.*, 2013)	Korea (origem mongol)	2011-2012	Dinnova system (Willmed, Gwangmyeong, Korea)	0.167mm	976	28.8 (13-69)	460/516	1952
18	(Kim S *et al.*, 2016)	Korea	2011-2012	Dinnova system (Willmed, Gwangmyeong, Korea)	0.167mm	960	28.7 (13-75)	441/519	1920
19	(Kim Y *et al.*, 2017)	Korea	2011-2012	Dinnova system (Willmed, Gwangmyeong, Korea)	0.167mm	979	28.81	462/517	1958
20	(Krishnamurthy *et al.*, 2017)	India	NA	SCANORA® 3D machine	0.1mm	30	7 (5-10)	13/17	60
21	(Martins *et al.*, 2017)	Portugal	2011-2016	Planmeca scanner (Planmeca Promax, Planmeca, Finland)	0.2mm	646	51	228/418	1117
22	(Martins *et al.*, 2018)	China	NA	Kodak scanner (Kodak 9500; Carestream, Atlanta, GA)	0.2mm	120	28	54/66	460
		Portugal	NA	Planmeca scanner (Planmeca Promax; Planmeca, Helsinki, Finland)	0.2mm	670	51	243/427	1153
23	(Mashyakhy *et al.*, 2019)	Saudi Arabia	NA	3D Accuitomo 170 (MORITA, Japan)	0.25mm	98	NA (15-50)	61/37	174
24	(Miloglu *et al.*, 2013)	Turkey	2010-2011	NewTom FP QR-DVT, Verona, Italy	NA	307	23.9 (12-69)	120/187	533
25	(Pan *et al.*, 2019)	Malaysia	NA	KaVo 3D eXam imaging system (Imaging Sciences International, Hatfield, PA, USA)	0.25mm	208	28.7 (15-66)	90/118	746
26	(Park *et al.*, 2013)	Korea	2008-2011	NA	NA	430	38.1 (19-70)	194/236	1436
27	(Pawar *et al.*, 2017)	India	2014-2015	ProMax 3D Mid (Planmeca OY, Helsinki, Finland)	0.1mm	983	26.8 (15-60)	489/494	983

28	(Pérez-Heredia *et al.*, 2017)	Spain	2014-2015	9300 3D CBCT unit (Carestream Dental, Atlanta, GA)	0.18mm	112	36.8 (18-62)	56/56	242
29	(Pham & Le, 2019)	Vietnam	2010-2016	Picasso Trio (Ewoo Vatech, Korea)	0.1 mm	166	NA (18- >50)	94/72	332
30	(Poonam & Hans, 2017)	India	2012-2014	Simulix Evolution (Nucletron, Chennai, India Pvt Ltd)	NA	1011	NA (18-45)	618/393	2022
31	(Qiao *et al.*, 2020)	China	2017-2018	3-dimension Accuitomo, J. MORITA MFG.CORP.Kyoto Japan)	0.125mm	587	NA	237/350	1174
32	(Riyahi *et al.*, 2019)	Saudi Arabia	2014-2018	ProMax 3D Max machine (Planmeca, Helsinki, Finland)	0.2-0.6mm	379	NA	204/175	1327
33	(Rivera, 2019)	Peru	2013-2014	SIRONA® - GALILEOS (Alemania) modelo GAX5	0.5mm	109	30.18 (18-60)	47/62	218
34	(Senan *et al.*, 2020)	Yemen	2016-2018	Pax-Flex3D imaging system (VATECH Global, Hwaseong-si, Korea)	0.12mm	250	24.2 (18-40)	125/125	500
35	(Sharaan & Elrawdy, 2017)	Egypt	2015-2017	Scanora 3D Imaging System (Sordex, Helsinki, Finland)	0.133mm	109	NA (15-49)	39/70	436
36	(Shemesh *et al.*, 2015)	Israel	2009-2012	ASAHI Alioth CBCT (Alioth; Asahi Roentgen IND, Kyoto, Japan)	0.15mm	1020	43.05 (13-89)	447/573	2694
37	(Silva *et al.*, 2013)	Brazil	2010-2011	i-CAT system (Imaging Sciences International, Hatfield, PA)	0.2mm	154	NA	70/84	460
38	(Torres *et al.*, 2015)	Belgium	2010-2012	3D Accuitomo 170® machine (Morita, Kyoto, Japan)	0.25mm	100	19.5 (11-47)	52/48	257
		Chile	2007-2012	3D Accuitomo 170® machine (Morita, Kyoto, Japan)	0.25mm	170	19 (11-60)	76/94	258
39	(Tu *et al.*, 2009)	Taiwan	2005-2008	(i-CAT; Xoran Technologies, Ann Arbor, MI; and Imaging Sciences International, Hatfield, PA)	0.2-0.4mm	123	36.1 (9-81)	59/64	246
40	(Wang *et al.*, 2010)	China	2009-2010	3D Accuitomo MCT-1 (EX-2F), J. Morita, Kyoto, Japan	0.125mm	558	NA (12-75)	301/257	558
41	(Zhang R *et al.*, 2011)	China	2009-2010	3D AccuitomoTomograph (Morita, Kyoto, Japan),	0.125mm	211	37 (18-57)	101/110	389

42	Zhang X *et al.*, 2015)	China	2013-2014	Galileos, Sirona, Germany	0.125mm	455	NA	257/198	910

Abbreviations: CBCT, cone-beam computed tomographic; NA, not available; NA* (only teeth analysis).

TABLE 2 Summary of descriptive results of included studies for first (Table 2a) and second (Table 2b) molars.

Study	**Number of first molar**	**FIRST MOLAR**													
		Males					**Females**					**Total (including no-gender cases)**			
		Number of teeth	**RE (%)**	**RP (%)**	**3R (%)**	**4R (%)**	**Number of teeth**	**RE (%)**	**RP (%)**	**3R (%)**	**4R (%)**	**RE (%)**	**RP (%)**	**3R (%)**	**4R (%)**
1	741	417	12 (2.8%)	2 (0.4%)	NE	NE	324	19 (5.8%)	0	NE	NE	31 (4.2%)	2 (0.3%)	NE	NE
2	400	209	30 (14.3%)	NE	NE	NA	191	19 (5.8%)	NE	NE	NA	50 (12.5%)			2 (0.5%)
3	174	73	12 (16.4%)	NE	NE	NE	101	7 (6.9%)	NE	NE	NE	19 (10.9%)	NE	NE	NE
4	384	183	NA	NA	5 (2.7%)	0	201	NA	NA	9 (4.4%)	0	NA	NA	14 (3.6%)	0
5	823	362	9 (2.4%)	NE	NE	1 (0.2%)	461	8 (1.7%)	NE	NE	1 (0.2%)	17 (2%)	NE	NE	2 (0.2%)
6	1318	540	11 (2%)	NE	NE	NE	778	14 (1.7%)	NE	NE	NE	25 (1.9%)	NE	NE	NE
7	384	193	12 (6.2%)	NE	NE	NE	191	10 (5.5%)	NE	NE	NE	* 22 (5.7%)	NE	NE	NE
8	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
9	256	NA	NE	NE	NA	NE	NA	NE	NE	NA	NE	NE	NE	31 (12.1%)	NE
10	200	NA	NA	NE	NE	NE	NA	NA	NE	NE	NE	6 (3%)	NE	NE	NE
11	237	119	37 (31%)	NE	NE	NE	118	23 (19.5%)	NE	NE	NE	60 (25.3%)	NE	NE	NE
12	129	NA	NE	NE	NA	NE	NA	NE	NE	NA	NE	NE	NE	5 (3.9%)	NE
13	780	414	107 (25.8%)	NE	NE	NE	366	84 (22.9%)	NE	NE	NE	191 (24.4%)	NE	NE	NE
14 *	478	197	5 (2.5%)	2 (1%)	NE	NE	281	5 (1.7%)	4 (1.4%)	NE	NE	12 (2.5%)	6 (1.2%)	NE	NE
15	864	446	109 (24.4%)	NE	NE	NE	418	92 (22%)	NE	NE	NE	201 (23.3%)	NE	NE	NE
16	2800	1408	349 (24.8%)	NE	NE	NE	1392	290 (20.8%)	NE	NE	NE	629 (22.8%)	NE	NE	NE
17	1952	920	250 (27.1%)	NE	NE	NE	1032	254 (24.6%)	NE	NE	NE	504 (25.8%)	NE	NE	NE
18	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
19	1958	NA	NA	NE	NE	NE	NA	NA	NE	NE	NE	507 (25.8%)	NE	NE	NE

20	60	26	2 (7.6%)	NE	NE	NE	34	5 (14.7%)	NE	NE	NE	7 (11.7%)	NE	NE	NE
21	450	NA	NA	0	NE	NE	NA	NA	0	NE	NE	10 (2.2%)	0	NE	NE
22	220 (C)	NA	NA	NA	NE	NE	NA	NA	NA	NE	NE	57 (25.9%)	0	NE	NE
	466 (P)	NA	NA	NA	NE	NE	NA	NA	NA	NE	NE	12 (2.6%)	0	NE	NE
23	174	111	4 (3.6%)	NE	NE	NE	63	1 (1.5%)	NE	NE	NE	5 (2.9%)	NE	NE	NE
24	533	NA	NA	NE	NE	NE	NA	NA	NE	NE	NE	13 (2.4%)	NE	NE	NE
25	370	153	32 (20.9%)	0	NE	NE	216	47 (21.7%)	0	NE	NE	80 (21.6%)	0	NE	NE
26	726	345	79 (22.8%)	0	NE	NE	382	83 (21.7%)	0	NE	NE	162 (22.3%)	0	NE	NE
27	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
28	121	NA	NE	NE	NA	NE	NA	NE	NE	NA	NE	NE	NE	5 (4.1%)	NE
29	332	188	26 (13.8%)	NE	NE	NE	144	15 (10.4%)	NE	NE	NE	41 (12.3%)	NE	NE	NE
30	2022	NA	NA	NE	NE	NE	NA	NA	NE	NE	NE	46 (2.2%)	NE	NE	NE
31	1174	474	129 (27.1%)	NE	NE	NE	700	151 (21.6%)	NE	NE	NE	280 (23.9%)	NE	NE	NE
32	655	NA	NE	NE	NA	NE	NA	NE	NE	NA	NE	NE	NE	20 (3%)	NE
33	218	94	NE	NE	6 (6.3%)	NE	124	NE	NE	6 (4.8%)	NE	NE	NE	12 (5.5%)	NE
34	500	250	4 (1.6%)	0	NE	NE	250	12 (4.8%)	0	NE	NE	16 (3.2%)	0	NE	NE
35	218	78	1 (1.2%)	NE	NE	NE	140	0	NE	NE	NE	1 (2.1%)	NE	NE	NE
36	1229	550	15 (2.7%)	1 (0.1%)	NE	0	679	10 (1.4%)	6 (0.8%)	NE	0	25 (2%)	7 (0.5%)	NE	0
37	234	NA	NA	NE	NE	NE	NA	NA	NE	NE	NE	0	NE	NE	NE
38	145 (B)	NA	NA	NE	NE	NA	NA	NA	NE	NE	NA	4 (2.7%)	NE	NE	0
	146 (C)	NA	NA	NE	NE	NA	NA	NA	NE	NE	NA	9 (6.1%)	NE	NE	0
39	246	118	30 (25.4%)	NE	NE	NE	128	33 (25.7%)	NE	NE	NE	63 (25.6%)	NE	NE	NE
40	558	301	68 (22.5%)	NE	NE	NE	257	76 (29.5%)	NE	NE	NE	144 (25.8%)	NE	NE	NE
41	232	NA	NA	NE	NE	NA	NA	NA	NE	NE	NA	68 (29%)	NE	NE	1 (0.4%)
42	910	514	121 (23.5%)	NE	NE	NE	396	80 (20.2%)	NE	NE	NE	202 (22.1%)	NE	NE	NE
TOTAL	**25.817**	**8.683**	**1.454 (16.7%)**	**5 (0.05%)**	**11 (0.1%)**	**1 (0.01%)**	**9.367**	**1.338 (14.2%)**	**10 (0.1%)**	**15 (0.1%)**	**1 (0.01%)**	**3.519 (13.6%)**	**15 (0.06%)**	**87 (0.3%)**	**5 (0.01%)**

(*) recalculado

Abbreviations: NA, not available; NE, not evaluated; 3R, three-rooted; 4R, four-rooted; (C) (P) (B) (C), countries according to the study

Study	Number of second molar	SECOND MOLAR													
		Males					Females					Total (including no-gender cases)			
		Number of teeth	RE (%)	RP (%)	3R (%)	4R (%)	Number of teeth	RE (%)	RP (%)	3R (%)	4R (%)	RE (%)	RP (%)	3R (%)	4R (%)

1	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
3	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
4	421	185	NA	NA	1 (0.5%)	0	236	NA	NA	1 (0.4%)	1 (0.4%)	NA	NA	2 (0.4%)	1 (0.2%)
5	925	409	17 (4.1%)	NE	NE	5 (1.2%)	516	15 (2.9%)	NE	NE	3 (0.5%)	32 (3.4%)	NE	NE	8 (0.8%)
6	1482	702	8 (1.1%)	NE	NE	NE	780	1(0.1%)	NE	NE	NE	9 (0.6%)	NE	NE	NE
7	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
8	190	81	0	5 (6.1%)	NE	NE	109	0	0	NE	NE	0	5 (2.6%)	NE	NE
9	311	NA	NE	NE	NA	NE	NA	NE	NE	NA	NE	NE	NE	12 (3.9%)	NE
10	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
11	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
12	198	NA	NE	NE	NA	NE	NA	NE	NE	NA	NE	NE	NE	6 (3%)	NE
13	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
14	(*) 523	207	6 (2.8%)	3 (1.4%)	NE	NE	316	14 (4.4%)	3 (0.9%)	NE	NE	15 (2.8%)	11 (2%)	NE	NE
15	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
16	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
17	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
18	1920	882	4 (0.4%)	3 (0.3%)	NE	NE	1038	5 (0.4%)	2 (0.1%)	NE	NE	9 (0.4%)	5 (0.2%)	NE	NE
19	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
20	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
21	667	NA	NA	NE	NE	NE	NA	NA	NE	NE	NE	4 (0.6%)	14 (2%)	NE	NE
22	240 (C)	NA	NA	NA	NE	NE	NA	NA	NA	NE	NE	2 (0.8%)	0	NE	NE
	687 (P)	NA	NA	NA	NE	NE	NA	NA	NA	NE	NE	8 (1.1%)	10 (1.4%)	NE	NE
23	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
24	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
25	376	NA	NA	NA	NE	NE	NA	NA	NA	NE	NE	1 (0.6%)	0	NE	NE
26	710	337	8 (2.3%)	1 (0.2%)	NE	NE	373	8 (2.1%)	0	NE	NE	16 (2.3%)	1 (0.1%)	NE	NE
27	983	489	55 (11.2%)	NE	NE	NE	494	19 (3.8%)	NE	NE	NE	74 (7.5%)	NE	NE	NE
28	121	NA	NE	NE	NA	NE	NA	NE	NE	NA	NE	NE	NE	0	NE
29	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
30	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
31	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
32	672	NA	NE	NE	NA	NE	NA	NE	NE	NA	NE	NE	NE	10 (1.4%)	NE
33	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
34	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
35	218	78	0	NE	NE	NE	140	0	NE	NE	NE	0	NE	NE	NE
36	1465	651	1 (0.1%)	8 (1.2%)	NE	4 (0.6%)	814	5 (0.6%)	12 (1.4%)	NE	4 (0.4%)	6 (0.4%)	20 (1.3%)	NE	8 (0.5%)
37	226	NA	NA	NE	NE	NE	NA	NA	NE	NE	NE	8 (3.5%)	NE	NE	NE
38	112 (B)	NA	NA	NE	NE	NA	NA	NA	NE	NE	NA	1 (0.8%)	NE	NE	1 (0.8%)
	112 (C)	NA	NA	NE	NE	NA	NA	NA	NE	NE	NA	4 (3.5%)	NE	NE	1 (0.8%)

39	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
40	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
41	157	NA	NA	NE	NE	NA	NA	NA	NE	NE	NA	2 (1.2%)	NE	NE	0
42	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
TOTAL	**12.716**	**4.021**	**99 (2.4%)**	**20 (0.4%)**	**1 (0.02%)**	**9 (0.2%)**	**4.816**	**67 (1.3%)**	**17 (0.3%)**	**1 (0.02%)**	**8 (0.1%)**	**191 (1.5%)**	**66 (0.5%)**	**30 (0.2%)**	**19 (0.1%)**

(*) recalculado

Abbreviations: NA, not available; NE, not evaluated; 3R, three-rooted; 4R, four-rooted; (C) (P) (B) (C), countries according to the study

The number of additional roots in men and women was 1 600 and 1 457, respectively, and more predominant in first molars (13.97%) than second molars (2.3%). When nominated, RE (15.1%) was more predominant than the RP variation (0.56%). Mandibular first molars had a higher predominance of RE (13.6%) when compared to second molars (1.5%). In contrast, RP was more predominant in mandibular second molars (0.5%), compared with first molars (0.06%). When the study described the additional root as a third root, the first molars were more frequently affected (0.3%), and an additional fourth root was more prevalent in second molars (0.1%). Overall, additional roots are more commonly found in Asian countries, especially in East Asia, with prevalence ranging from 19% to 25.4% (Table S5) (Figure 2).

Figure 2. Global map demonstrating prevalence of additional root in first (2a) and second (2b) molars distributed by country.

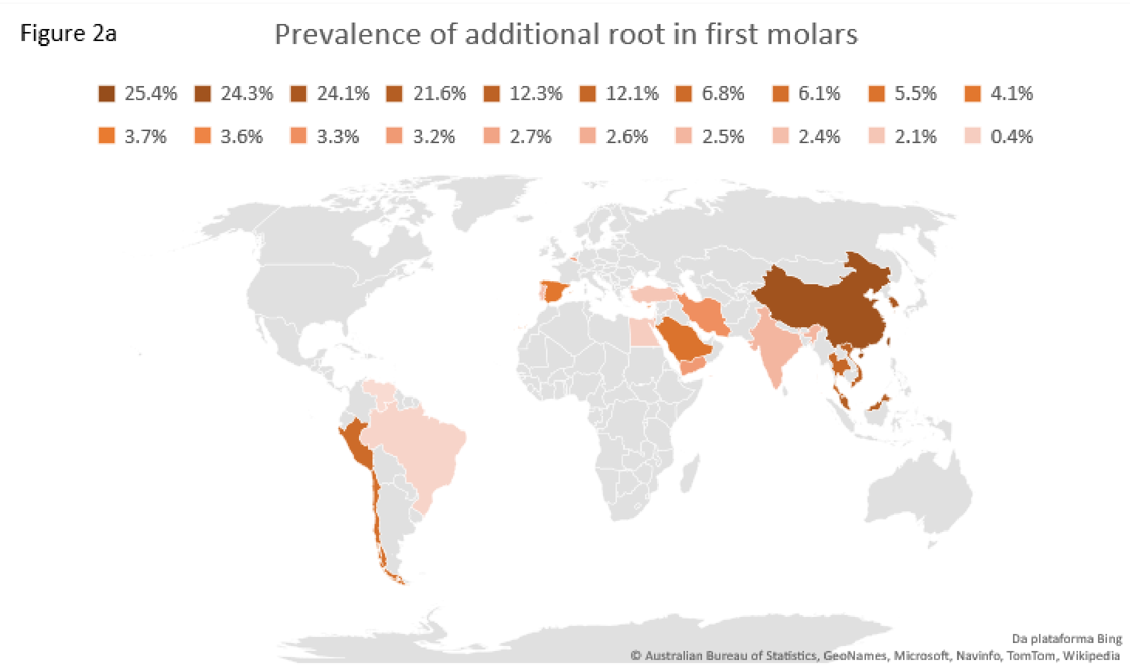
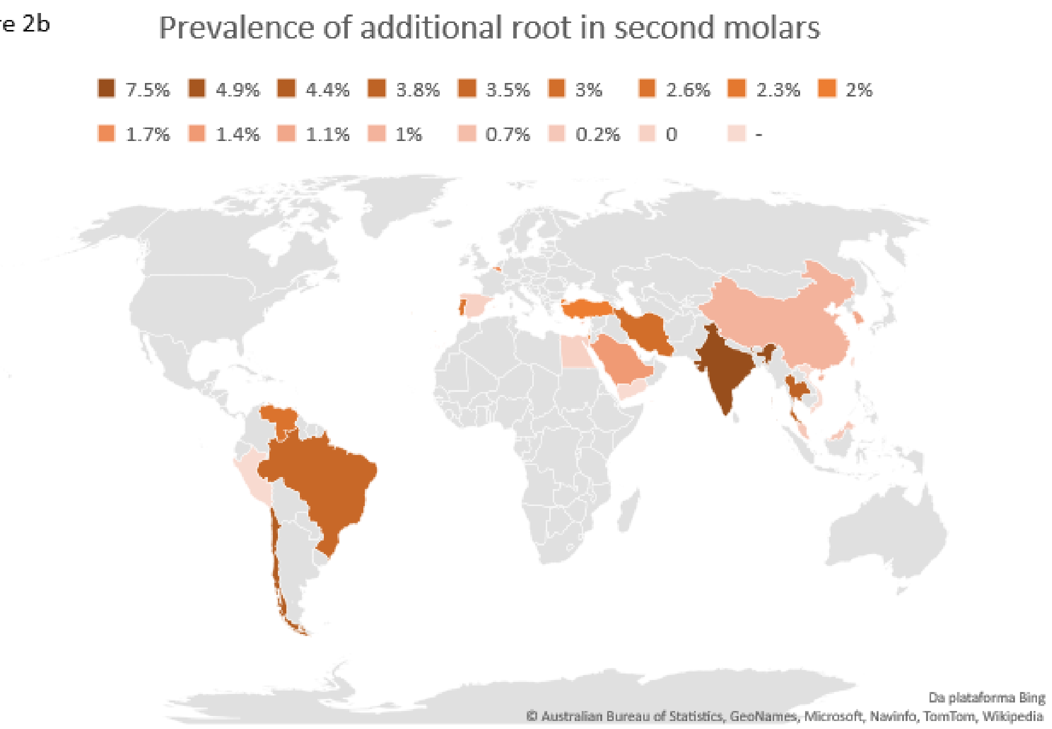


Figure 2b



Risk of bias

The results for risk of bias according to JBI criteria were categorized as high, unclear, or low (Figure 3). Most of the analysed criteria (i.e., adequateness of the target population, detailed description of the study subjects and setting, and appropriateness of statistical analysis) had a low risk of bias, whereas two specific criteria were scored mainly as having a high risk of bias: adequacy of sample size (76.2%) and measurement following standard and reliable conditions (61.9%). Overall, most of the included studies (71.4%) were classified as having a low risk of bias.

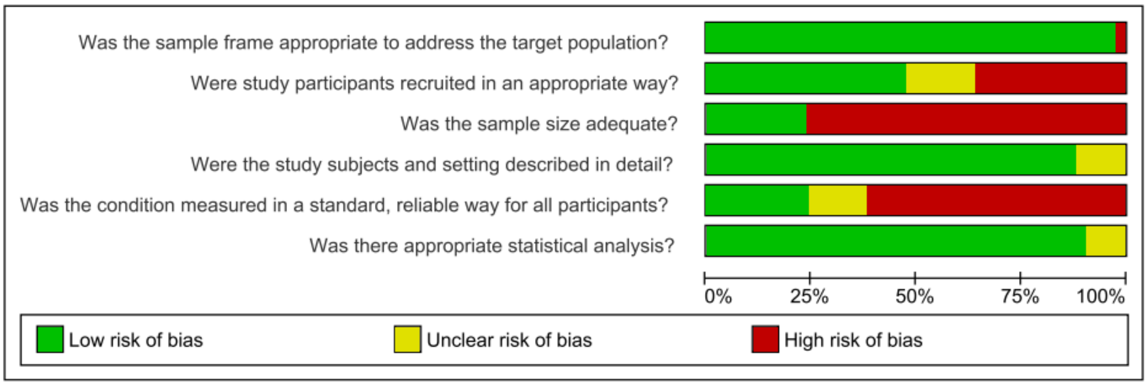
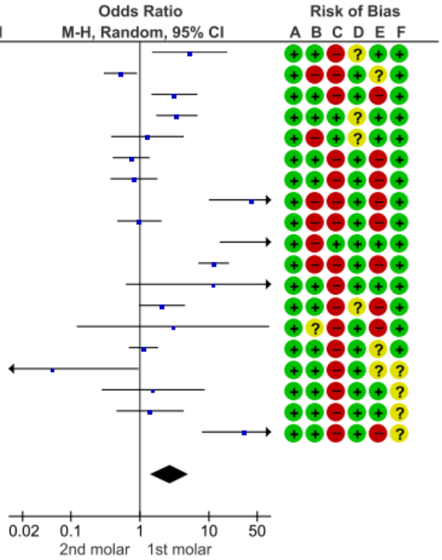


Figure 3. Summary of the risk of bias ratings of each item considered in the review.

According to Figure 4, the occurrence of an additional root was greater in first molars as compared to second molars (OR 2.72, 95% CI 1.42, 5.19; p = 0.003). However, heterogeneity was considered high in this analysis ($I^2 = 89\%$). To minimize the effects of heterogeneity, a subgroup analysis comparing first and second molars was also conducted by differentiating studies in terms of the type of radix (Figure 5).

Study or Subgroup	1st molar Events	1st molar Total	2nd molar Events	2nd molar Total	Weight	Odds Ratio M-H, Random, 95% CI
Celikten et al. 2016	14	384	3	421	5.4%	5.27 [1.50, 18.49]
Demirbuga et al. 2013	19	823	40	925	6.4%	0.52 [0.30, 0.91]
Duman et al. 2020	25	1318	9	1482	6.1%	3.16 [1.47, 6.80]
Hiran et al. 2021	31	256	12	311	6.2%	3.43 [1.72, 6.83]
Jamshidi et al. 2021	5	129	6	198	5.4%	1.29 [0.39, 4.32]
Kantilieraki et al. 2019	18	478	26	523	6.3%	0.75 [0.40, 1.38]
Martins et al. 2017	10	450	18	667	6.1%	0.82 [0.37, 1.79]
Martins et al. 2018	57	220	2	240	5.1%	41.61 [10.02, 172.85]
Martins et al. 2018	12	466	18	687	6.2%	0.98 [0.47, 2.06]
Pan et al. 2019	80	370	1	376	4.1%	103.45 [14.31, 747.84]
Park et al. 2013	162	726	17	710	6.4%	11.71 [7.02, 19.54]
Pérez-Heredia et al. 2017	5	121	0	121	2.9%	11.47 [0.63, 209.79]
Riyahi et al. 2019	20	655	10	672	6.1%	2.09 [0.97, 4.49]
Sharaan et al. 2017	1	218	0	218	2.5%	3.01 [0.12, 74.39]
Shemesh et al. 2015	32	1229	34	1465	6.5%	1.13 [0.69, 1.83]
Silva et al. 2013	0	234	8	226	2.9%	0.05 [0.00, 0.96]
Torres et al. 2015	4	145	2	112	4.6%	1.56 [0.28, 8.68]
Torres et al. 2015	9	146	5	112	5.6%	1.41 [0.46, 4.32]
Zhang et al. 2011	69	232	2	157	5.1%	32.81 [7.91, 136.12]
Total (95% CI)		**8600**		**9623**	**100.0%**	**2.72 [1.42, 5.19]**
Total events	573		213			

Heterogeneity: Tau² = 1.63; Chi² = 170.38, df = 18 (P < 0.00001); I² = 89%
Test for overall effect: Z = 3.02 (P = 0.003)



Risk of bias legend
(A) Was the sample frame appropriate to address the target population?
(B) Were study participants recruited in an appropriate way?
(C) Was the sample size adequate?
(D) Were the study subjects and setting described in detail?
(E) Was the condition measured in a standard, reliable way for all participants?
(F) Was there appropriate statistical analysis?

Figure 4. Summary findings of the overall pairwise meta-analysis comparing the effects of the type of tooth (1st vs 2nd molars) on the occurrence of additional root. The analysis was conducted using the odds ratio (OR) estimate and using a random-effects model with 95% confidence intervals (95%CI). The risk of bias of each study per analysis is also presented.

As shown in Figure 5, there was no statistically significant difference between first and second molars if the type of radix was not specified in the study (p = 0.34), although upon proper identification of the type of radix, significant differences were demonstrated. While RE occurred more frequently in first molars (OR 3.96, 95% CI 1.69, 9.28; p = 0.002), RP has a lower likelihood of occurring in first molars than second molars (OR 0.36, 95% CI 0.17, 0.76; p = 0.007). Overall, first molars remained slightly the type of tooth most frequently affected by an additional root (OR 1.81, 95% CI 1.01, 3.26; p = 0.05).

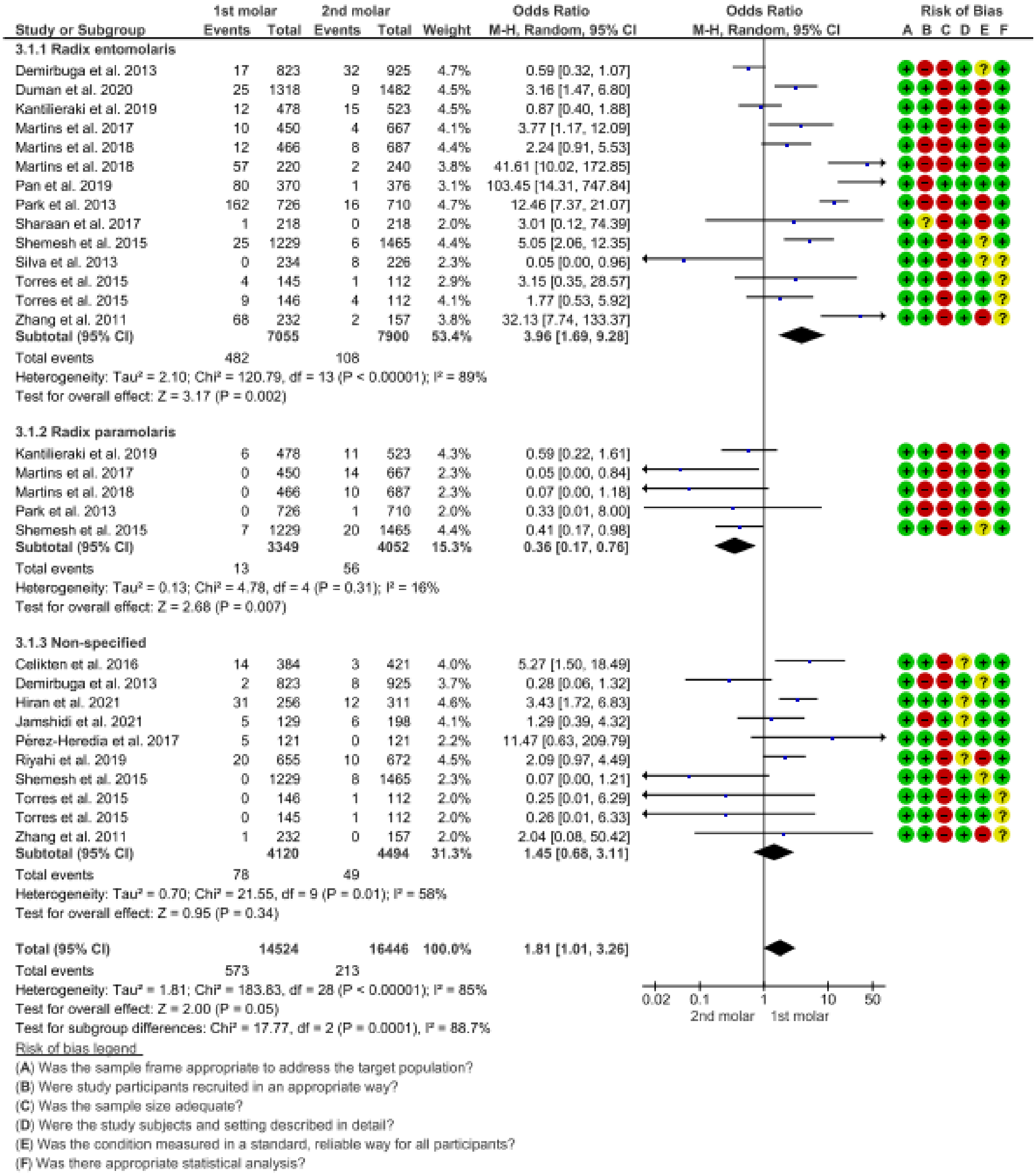


Figure 5. Summary findings of the subgroup pairwise meta-analyses comparing the effects of the type of tooth (1st vs 2nd molars) on the occurrence of additional root categorized per type of radix (entomolaris, paramolaris, and non-specified). The analyses were conducted using the odds ratio (OR) estimate and using random-effects models with 95% confidence intervals (95%CI). The risk of bias of each study per analysis is also presented.

The occurrence of an additional root in mandibular molars was also investigated by having the sex of individuals as the main variable. The type of tooth was a significant factor in this set of analyses (Figure 6), with men showing a greater likelihood of having an additional root in mandibular molars than women (OR 1.18, 95% CI 1.05, 1.33; p = 0.007). However, this effect was significant for first molars only (p = 0.008), whereas for second molars the occurrence of radix did not differ between males and females (p = 0.11). The overall heterogeneity of this set of analyses was considered low (I^2 = 35%). On the other hand, men and women showed a similar occurrence of an additional root in mandibular molars regardless of the type of radix (Figure 7). Heterogeneity was considered moderate to high in this set of analyses (I^2 = 70%).

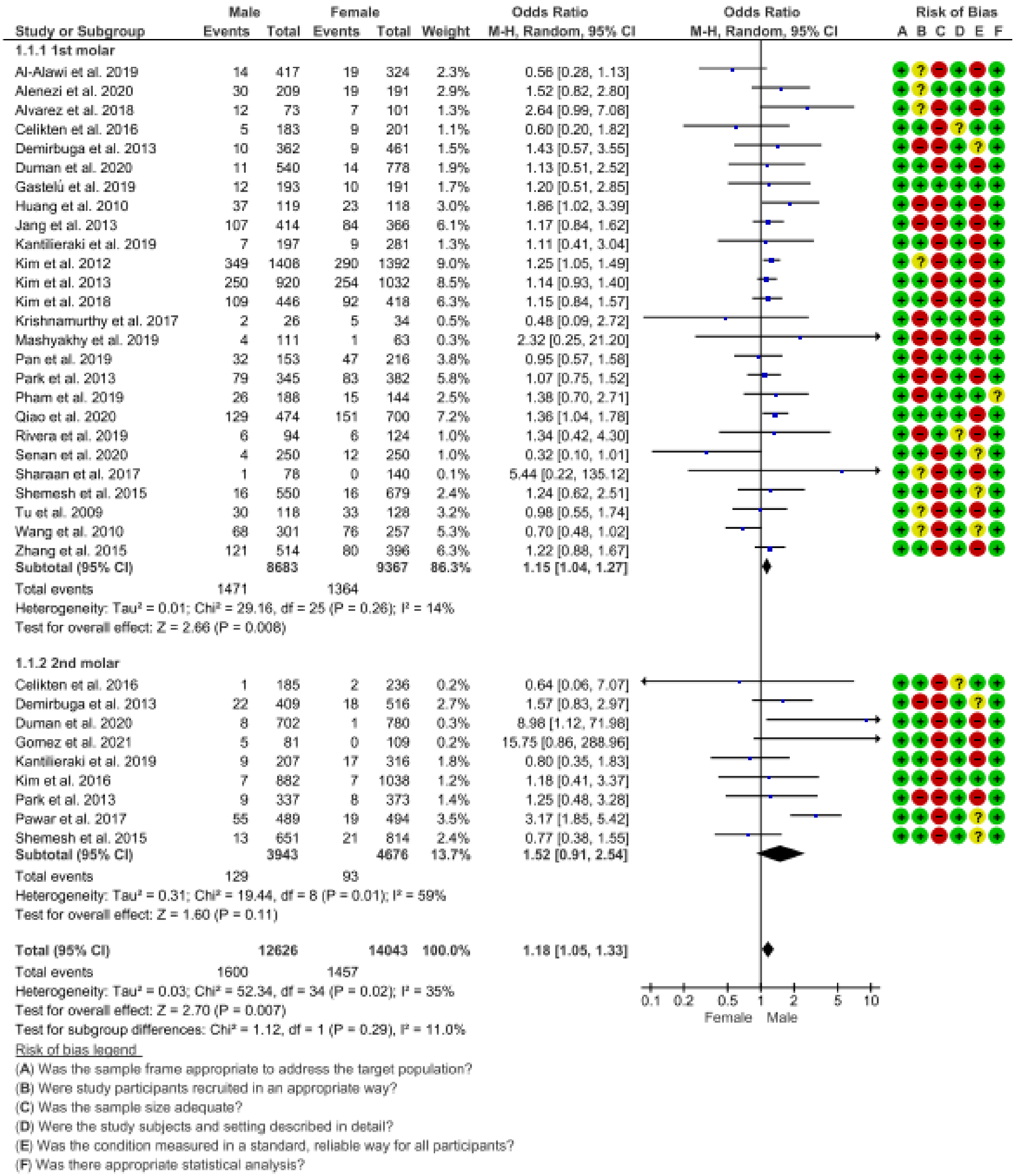


Figure 6. Summary findings of the subgroup pairwise meta-analyses comparing the effects of sex (male vs female) on the occurrence of additional root categorized per type of tooth (1st molar and 2nd molar). The analyses were conducted using the odds ratio (OR) estimate and using random-effects models with 95% confidence intervals (95%CI). The risk of bias of each study per analysis is also presented.

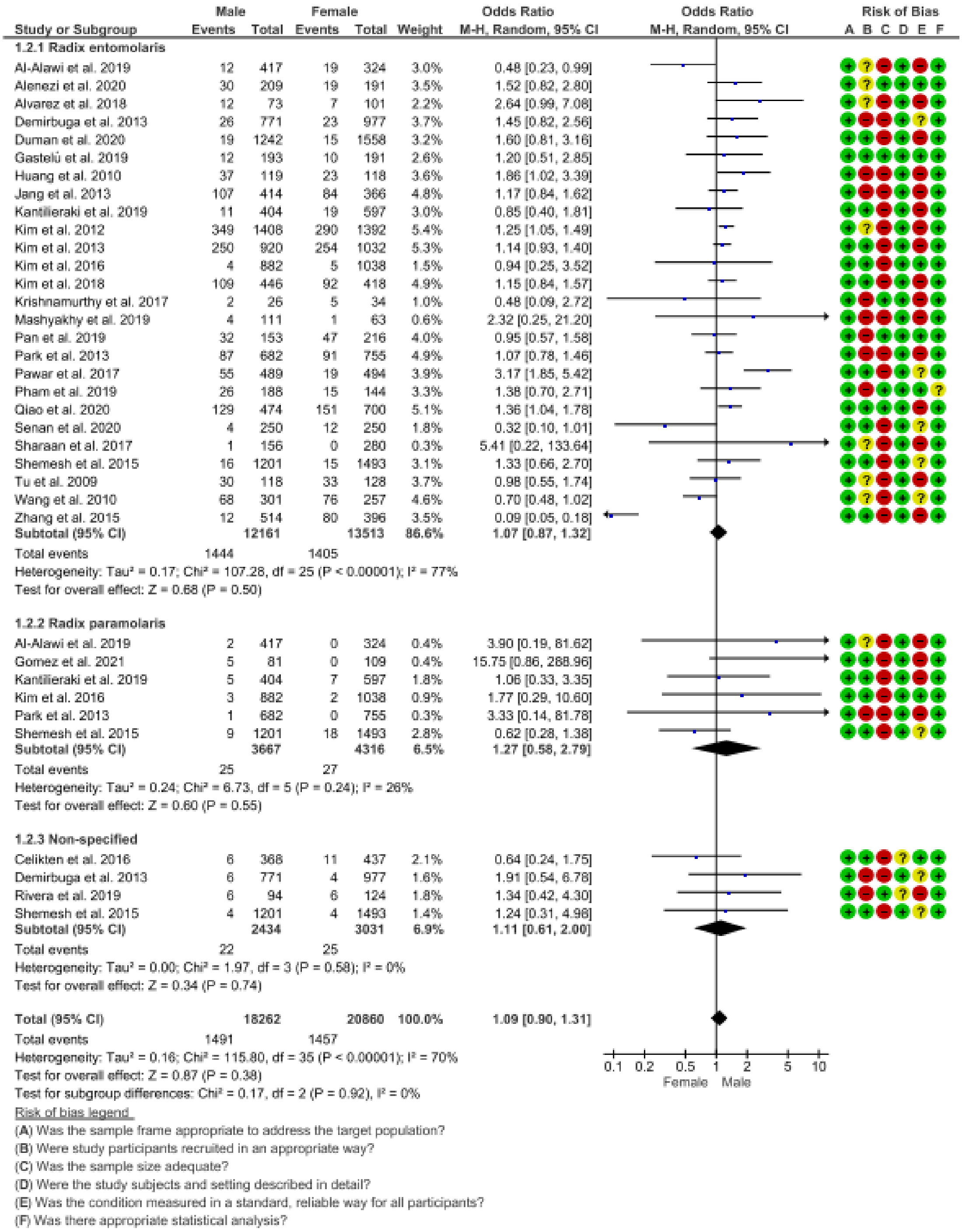


Figure 7. Summary findings of the subgroup pairwise meta-analyses comparing the effects of sex (male vs female) on the occurrence of additional root categorized per type of radix (entomolaris, paramolaris, and non-specified). The analyses were conducted using the odds ratio (OR) estimate and using random-effects models with 95% confidence intervals (95%CI). The risk of bias of each study per analysis is also presented.

Funnel plot results for all main comparisons performed in this review are shown in Figure 8, which demonstrate no significant publication bias across the studies. Egger's test confirmed these observations: overall analysis (p = 0.412; image a); subgroup analysis testing the effect of the type of radix (p = 0.089; image b); subgroup analysis testing the effect of sex (p = 0.165; image c); and subgroup analysis testing the effect of sex on the distribution of different types of radix (p = 0.145; image d).

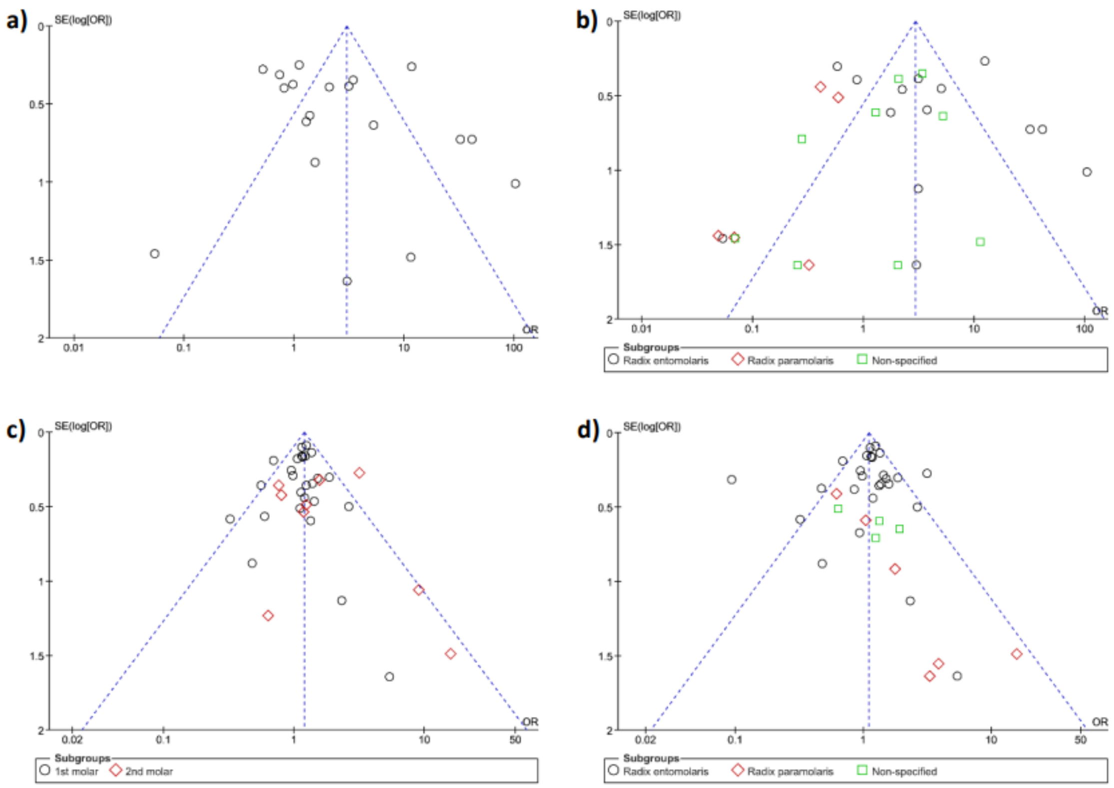


Figure 8. Funnel plot graphs for overall standard error (SE) versus odds ratio (OR) values of the occurrence of additional root. The results demonstrate an apparent absence of publication bias across the studies in terms of the overall prevalence of radix in 1st vs 2nd molars (a) and in the subgroup analyses comparing the effects of the type of tooth on different types of radix (b), and the effects of sex on subgroups categorized per the type of tooth (c) and type of radix (d).

Discussion

One of the main reasons for endodontic failure is an untreated canal. Indeed, the dentist may fail to identify extra roots and root canals (Vertucci & Gainesville 1884), ultimately leading to important implications for endodontic therapy (Al-Alawi *et al.* 2020).

Permanent mandibular molars have great anatomical variation in which the presence of an additional root can be verified (Miloglu *et al.* 2013, Kim *et al.* 2018, Kantilieraki *et al.* 2019). It should be noted that multiple intraoral radiographs do not guarantee the identification of all relevant anatomy of the intracanal system (Abella *et al.* 2011), hampering the identification of an additional root on mandibular molars, especially when the roots overlap giving the illusion of the presence of only one root (Zhang *et al.* 2011). CBCT is not considered a standard method for diagnosis in endodontics, but it is indicated in cases where intraoral radiography provides inadequate or uncertain information for the detection of anatomy and treatment planning, especially in multirooted teeth (Sedentexct 2011). The American Association of Endodontists (AAE) and the American Academy of Oral and Maxillofacial Radiology (AAOMR) indicate the use of CBCT for specific cases, e.g., during the initial treatment of teeth with suspicious potential for extra canals and complex morphology (AAE/AAOMR 2015). The identification of three roots in the mandibular first molar is higher when CBCT is used when compared with conventional radiograph as a diagnostic tool (Tu *et al.* 2007, 2009).

The current study is the first systematic review and meta-analysis to assess the presence of an additional root in first and second mandibular molars using CBCT, including subgroups such as sex, tooth, and location of the additional root. Furthermore, the prevalence by geographic region was evaluated. In this regard, the results demonstrated herein will contribute to clinical practice, as they alert clinicians to the prevalence and predisposing factors of atypical morphology in mandibular molars. This should include an attentive search for additional roots or even CBCT indication before treatment planning, especially in first molars, men, and people of Asian ethnicity.

The study was initially registered in PROSPERO, providing transparency. Nine databases were used to search for studies. In addition, we used a checklist for prevalence studies (JBI) associated with the recently published guideline for reporting prevalence studies using CBCT (Martins *et al.* 2020). This study analysed data gathered from a large number of teeth (38 533 first and second mandibular molars) from a total of 42 articles. This large sample improves the quality of the study.

The occurrence of an additional root in mandibular molars may rely on ethnic, genetic predisposition and geographical features (Zhang *et al.* 2015). The present review demonstrates that East Asia presents the highest prevalence of an additional root (19.7%), and that Taiwan (25.4%), China (21.6%), and Korea (19%) are the most affected countries. Other geographic locations such as South/Southeast Asia, America, Europe, and the Middle East presented an average prevalence of 6.1% (4.1–12.3%), 4.7% (1.7–6.8%), 2.9% (2–4.3%), and 2.7% (0.2–4.5%), respectively. In agreement, a higher prevalence of this condition in Asia has been previously observed (Tu *et al.* 2007, Chen *et al.* 2009, Song *et al.* 2010, Wang *et al.* 2010, Jang *et al.* 2013, Park *et al.* 2013, Agarwal *et al.* 2015, Zhang *et al.* 2015, Al-Alawi *et al.* 2020).

In a systematic review that evaluated the root anatomy and canal configuration of the permanent mandibular first molar, the authors found an overall third root prevalence of 13%.

Moreover, this study showed that the Mongoloid population has 3 times more additional third roots compared to Caucasians and African Americans, emphasizing the ethnic predisposition for anatomical variations such as the number of roots (de Pablo *et al.* 2010).

One global meta-analysis was planned in this systematic review, which demonstrated that an additional root in mandibular molars is more frequently identified in first molars as compared with second molars (Nur *et al.* 2014, Celikten *et al.* 2016, Pérez-Heredia *et al.* 2017, Riyahi *et al.* 2019, Duman *et al.* 2020, Hiran-us *et al.* 2021). However, it is noteworthy that in a Greek population, second molars were considerably more affected with an additional root than first molars (Kantilieraki *et al.* 2019), differing from our findings. Taiwan had the highest prevalence of an additional root (25.4%) in the case of first molars, followed by China (24.3%), Korea (24.1%), and Malaysia (21.6%), whereas for second molars, India had the highest prevalence of an additional root (7.5%), followed by Greece (4.9%), Chile (4.4%), Thailand (3.8%), and Brazil (3.5%). However, this finding should be interpreted with caution since most of the included studies were conducted in Asia (32/42), which may suggest that the occurrence of an additional roots is more prevalent in this location, being a limitation of the study. Despite the greater occurrence of an additional root in the first mandibular teeth (as verified in this set of meta-analyses), heterogeneity was high ($I^2 = 89\%$), probably explained by the heterogeneous distribution of data. Thus, we conducted subgroup meta-analyses by allocating studies according to their similar characteristics.

In the first set of subgroup meta-analyses, the data on the prevalence of an additional root were allocated according to the radix classification: RE, RP, and the ‘non-specified’ subgroup, which was included since some of the studies (6/42) did not define exactly the location of the additional root; of note, the latter group was typically referred to in the studies as a third root, a supernumerary root, an extra root, as well as a fourth root (Rivera 2013, Celikten *et al.* 2016, Pérez-Heredia *et al.* 2017, Riyahi *et al.* 2019, Hiran-us *et al.* 2021, Jamshidi *et al.* 2021). This indefinite naming made this study difficult. Here, we did not exclude the studies, with the purpose of preventing a possible underestimation of the prevalence of an additional root in mandibular teeth.

The prevalence of RP is considered rare and less common when compared to RE (Calberson *et al.* 2007), corroborating our results (0.5% vs 13.6%, respectively). However, it was possible to observe a distinct trend between the distribution of RE and RP, with the former showing a higher likelihood of occurring in first molars and the latter in second molars. This finding corroborates those of other studies (Felsypremila *et al.* 2015, Duman *et al.* 2020), but according to Silva *et al.* (2013), who investigated this condition in a Brazilian population, there was no case of an additional root in first molars, although the second molars were affected with RE. Thus, it seems that multiple ethnic groups and their unique variability can influence the occurrence of an additional root in mandibular teeth (de Pablo *et al.* 2010). Concerning the non-specified subgroup, the meta-analysis failed to show a statistically significant difference between first and second molars, suggesting that in this group there was the presence of both RE and RP conditions. It is advisable that in future studies evaluating the prevalence of an additional root in mandibular teeth, the proper radix classification should be presented, allowing the adequate identification of which type of radix is more frequently distributed within different type of teeth.

Studies have reported an influence of sex on the occurrence of an additional root, although there is no consensus on this topic: while some studies showed a predominance for males (Kim & Yang 2012, Duman *et al.* 2020, Qiao *et al.* 2020), others identified that females are more affected by the condition (Riyahi *et al.* 2019, Senan *et al.* 2020). From the present findings, males showed a greater likelihood of having an additional root in first molars than females (Figure 6), and despite the lack of a statistically significant difference when considering the second molars, men were also 1.52 times more likely to be affected with an additional root. No less important, the overall effect of this set of meta-analyses confirmed the greater occurrence of an additional root in men (OR 1.18; 95% CI 1.05, 1.33; $p = 0.007$), probably explained by the aspects related to genetic inherence or due to the dentinogenesis process itself (Calberson *et al.* 2007, Agarwal *et al.* 2015, Alenezi *et al.* 2020;). This is the first review study that shows the greater predisposition of men to develop an additional root, although without any effects on the type of radix (Figure 7). Of note, there was no significant difference between males and females in terms of the localization of the additional root. Here, we may suggest that there must be a trigger point inducing the development of the additional root as discussed earlier, but without a specificity for the affected area of the tooth. Future studies focused on this topic are warranted to better elucidate the effects that genetic and environmental issues affecting the dentinogenesis process in men have on the development of an additional root.

Recently, a cross-sectional study with meta-analysis showed an overall prevalence of 5.6% of RE in first molars, occurring mainly in the East Asian population. In addition, it showed that sex had no influence on the prevalence of RE, which corroborates the findings of the present review. However, unlike the present study, it did not assess mandibular second molars and only includes data for the RE variation (Martins *et al.* 2022).

Assessment of the risk of overestimating or underestimating the true effect of the intervention is a critical part of a systematic review (Hopewell *et al.* 2013). Most of the included studies did not perform a sample size calculation (30/42) and did not provide sufficient data on how the samples were measured (33/42). Reinforcing the standardization aspect discussed up to here, the present review has observed that the non-uniform classification of the radix was a common scenario. One study classified the additional root as RE when the presence of a distolingual root was clearly separated from the distobuccal root (Kim *et al.* 2013). However, RE may appear as a separate or a non-separated root (Carlsen *et al.* 1990), so this study was excluded from the review. Furthermore, the use of an adequate nomenclature should improve future results regarding root morphology. One study considered the prevalence of an additional root per individual and not per tooth sample, which precluded adequate analysis (Rahimi *et al.* 2017). Also, the number of studies including second molars was low (n = 3) as compared with the investigation of mandibular first molars (n = 22) and both conditions (n = 17). The foregoing faults prevent reproducibility and may not contribute to the improvement of evidence-based practice in anatomy and endodontics.

Most of the included studies demonstrated methodological adequateness, presenting the specific characteristics of the population and exact location of the additional roots, and used adequate statistical methods to analyse the data. Thus, publication bias was not a concern in the present review, as demonstrated in the funnel plots shown in Figure 8 as well as by Egger's test. This was already expected since our review gathered data from cross-sectional studies, so the possibility of this type of bias occurring is reduced since there are minor methodological differences among the studies.

CBCT imaging is a reliable method to better understand root canal morphology, improving the identification of the presence of an additional root as well as the prevalence of this condition in the worldwide population, bringing important clinical implications for endodontic therapy. Therefore, this systematic review included only CBCT studies to prevent underestimation of extra root frequency (Neelakantan *et al.* 2010). CBCT provides a more accurate assessment because of some features such as the slice thickness and the higher image resolution (Patel *et al.* 2012, Torres *et al.* 2015). The additional root is a larger anatomical structure and no restriction on the voxel size was considered. In addition, a previous study demonstrated that there is no difference in the accuracy of measuring tooth length with a voxel from 0.4 to 0.2 mm (Sherrard *et al.* 2010).

Conclusion

The global prevalence of additional roots in permanent mandibular molars was 10.3%. Countries in East Asia presented the highest prevalence, with values ranging from 19% to 25.4%. First molars were affected more frequently with an additional root than second molars. For both teeth, RE was predominant when compared to RP. Men showed a greater likelihood of being affected with additional root in first molars than women.According to the findings of the present study, it is important for the dentist to be aware of possible anatomical variations of mandibular first and second molars, especially in Asian men. Furthermore, it is important to be aware that the type of radix will be more closely associated with a tooth type.

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REFERENCES

Abella F, Mercadé M., Duran-Sindreu F, Roig M (2011) Managing severe curvature of radix entomolaris: Three-dimensional analysis with cone beam computed tomography. *International Endodontic Journal* **44**(9), 876–885.

Agarwal M, Trivedi H P, Mathur M, Goel D, Mittal S (2015) The radix entomolaris and radix paramolaris: An endodontic challenge. *Journal of Contemporary Dental Practice* **15**(4), 496–499.

Al-Alawi H, Al-Nazhan, S, Al-Maflehi N, Aldosimani M A, Zahid M N, Shihabi G N (2020) The prevalence of radix molaris in the mandibular first molars of a Saudi subpopulation based on cone-beam computed tomography. *Restorative Dentistry & Endodontics*, **45**(1),e1.

Alenezi K, Alharbi B, Kolarkodi S (2020) Prevalence of three rooted mandibular permanent first molars in Qassim population in Saudi Arabia. *International Journal of Medicine in Developing Countries* **4**(11), 1797–1800.

Alvarez N, Alvarado C D (2018) Evaluación tomográfica radicular de molares mandibulares Root tomographic evaluation of mandibular molars. Lima, Peru: Universidad Inca Garcilaso de la Veja

Baruwa A O, Martins J N R, Meirinhos J *et al.* (2020) The Influence of Missed Canals on the Prevalence of Periapical Lesions in Endodontically Treated Teeth: A Cross-sectional Study. *Journal of Endodontics* **46**(1), 34-39.

Calberson F L, de Moor R J, Deroose C A (2007) The Radix Entomolaris and Paramolaris: Clinical Approach in Endodontics. *Journal of Endodontics* **33**(1), 58–63.

Cantatore G, Berutti E, Castellucci A (2006) Missed anatomy: frequency and clinical impact. *Endodontic Topics 2009* **15**, 3–31.

Carlsen O, Alexandersen V, Carlsen O (1990). Radix entomolaris: identification and morphology. *Department of Denial Morphology, Royal Denial College, Copenhagen, Denmark* **98**, 363-73.

Carlsen O, Alexandersen V, Carlsen O (1991). Radix paramolaris in permanent mandibular molars: identification and morphology. *Department of Denial Morphology, Royal Denial College, Copenhagen, Denmark* **99**, 189-95.

Celikten B, Tufenkci P, Aksoy U *et al.* (2016) Cone beam CT evaluation of mandibular molar root canal morphology in a Turkish Cypriot population. *Clinical Oral Investigations* **20**(8), 2221–2226.

Chen G, Yao H, Tong C (2009) Investigation of the root canal configuration of mandibular first molars in a Taiwan Chinese population. *International Endodontic Journal* **42**(11), 1044–1049.

Costa F F N P, Pacheco-Yanes J, Siqueira J F *et al.* (2019) Association between missed canals and apical periodontitis. *International Endodontic Journal* **52**(4), 400–406.

de Moor R J G, Deroose C A J G, Calberson F L G (2004) The radix entomolaris in mandibular first molars: an endodontic challenge. *International Endodontic Journal* **37**(11), 789–799.

de Pablo Ó V, Estevez R, Péix Sánchez M, Heilborn C, Cohenca N (2010) Root anatomy and canal configuration of the permanent mandibular first molar: A systematic review. *Journal of Endodontics* **36**(12), 1919–1931.

de Souza-Freitas J A, Lopes E S, Casati-Alvares L (1971) Anatomic variations of lower first permanent molar roots in two ethnic groups. *Oral surgery, oral medicine, and oral pathology* **31**(2), 274–278.

Demirbuga S, Sekerci A E, Dinçer A N, Cayabatmaz M, Zorba Y O (2013) Use of cone-beam computed tomography to evaluate root and canal morphology of mandibular first and second molars in Turkish individuals. *Medicina oral, patologia oral y cirugia bucal* **18**(4), 737–744.

Duman S B, Duman S, Bayrakdar I S, Yasa Y, Gumussoy I (2020) Evaluation of radix entomolaris in mandibular first and second molars using cone-beam computed tomography and review of the literature. *Oral Radiology* **36**(4), 320–326.

Durack C, Patel S (2012) Cone Beam Computed Tomography in Endodontics. *Brazilian dental journal* **23**(3), 179–191.

Felsypremila G, Vinothkumar T S, Kandaswamy D (2015) Anatomic symmetry of root and root canal morphology of posterior teeth in Indian subpopulation using cone beam computed tomography: A retrospective study. *European Journal of Dentistry* **9**(4), 500–507.

Gastelú E R D A (2019) Características morfológicas de radix entomolaris en molares inferiores evaluadas mediante tomografía cone beam en pacientes del Hospital De Policía Nacional Luis Nicasio Sáenz 2017. (Dissertation). Lima – Peru. Universidad Nacional Federico Villarreal

Gomez F, Brea G, Gomez-Sosa J F (2021) Root canal morphology and variations in mandibular second molars: an in vivo cone-beam computed tomography analysis. *BMC oral health* **21**(1), 424.

Higgins J P T, Thompson S G (2002) Quantifying heterogeneity in a meta-analysis. *Statistics in Medicine* **21**(11), 1539–1558.

Hiran-us S, Benjavongkulchai S, Antanit C, Thanadrob P, Thongpet P, Onrawijit A (2021) Prevalence of C-shaped Canals and Three-rooted Mandibular Molars Using CBCT in a Selected Thai Population. *Iranian Endodontic Journal* **16**(2), 97-102.

Hoen M M, Pink F E (2002) Contemporary Endodontic Retreatments: An Analysis based on Clinical Treatment Findings. *Journal of endodontics* **28**(12), 834–836.

Hopewell S, Boutron I, Altman D G, Ravaud P (2013) Incorporation of assessments of risk of bias of primary studies in systematic reviews of randomised trials: a cross-sectional study. *BMJ open* **3**(8), e003342.

Hosseini S, Soleymani A, Moudi E, Bagheri T, Gholinia H (2020) Frequency of middle mesial canal and radix entomolaris in mandibular first molars by cone beam computed tomography in a selected Iranian population. *Caspian J Dent Res* **9**, 63-70.

Huang C C, Chang Y C, Chuang M C *et al.* (2010) Evaluation of Root and Canal Systems of Mandibular First Molars in Taiwanese Individuals Using Cone-beam Computed Tomography. *Journal of the Formosan Medical Association* **109**(4), 303–308.

Jamshidi D, Tofangchiha M, Roohi N *et al.* (2021) Evaluation of the association between the number and configuration of root canals of mandibular molars in an Iranian subpopulation: A cone-beam computed tomography study. *Saudi Endodontic Journal* **11**(1), 93–99.

Jang J K, Peters O A, Lee W C, Son S A, Park J K, Kim H C (2013) Incidence of three roots and/or four root canals in the permanent mandibular first molars in a Korean sub-population. *Clinical Oral Investigations* **17**(1), 105–111.

Kantilieraki E, Delantoni A, Angelopoulos C, Beltes P (2019) Evaluation of root and root canal morphology of mandibular first and second molars in a Greek population: A CBCT study. *European Endodontic Journal* **4**(2), 62–68.

Kim H H, Jo H H, Min J B, Hwang H K (2018) CBCT study of mandibular first molars with a distolingual root in Koreans. *Restorative Dentistry & Endodontics* **43**(3), e33.

Kim S, Choi M R, Yoo J J (2013) Concurrent relationship between additional canals of mandibular first molars and maxillary first molars using cone-beam computed tomography. *Oral Radiology* **29**(2), 146–150.

Kim S Y, Yang S E (2012) Cone-beam computed tomography study of incidence of distolingual root and distance from distolingual canal to buccal cortical bone of mandibular first molars in a korean population. *Journal of Endodontics* **38**(3), 301–304.

Kim S Y, Kim B S, Woo J, Kim Y (2013) Morphology of Mandibular First Molars Analyzed by Cone-beam Computed Tomography in a Korean Population: Variations in the Number of Roots and Canals. *Journal of Endodontics* **39**(12), 1516–1521.

Kim S Y, Kim B S, Kim Y (2016) Mandibular second molar root canal morphology and variants in a Korean subpopulation. *International endodontic journal* **49**(2), 136–144.

Kim Y, Roh B, Shin Y, Kim BS, Choi Y, Ha A (2018) Morphological Characteristics and Classification of Mandibular First Molars Having 2 Distal Roots or Canals: 3-Dimensional Biometric Analysis Using Cone-beam Computed Tomography in a Korean Population. *Journal of Endodontics* **44**, 46–50.

Krishnamurthy N, Jacob C D, Thimmegowda U, Bhat P, Arali V, Bhat P (2017) Anatomical Configuration of Roots and Canal Morphology of Primary Mandibular First Molars: A CBCT Study. **11**(11), 09-11.

Loh H S (1990) Incidence and features of three-rooted permanent mandibular molars. *Australian Dental Journal* **35**(5), 434–437.

Magnucki G, Mietling S V K (2021) Four-Rooted Maxillary First Molars: A Systematic Review and Meta-Analysis. *International Journal of Dentistry* **2021,** 1-15.

Martins J, Marques D, Mata A, Caramês J (2017) Root and root canal morphology of the permanent dentition in a Caucasian population: a cone-beam computed tomography study. *International endodontic journal*, **50**(11), 1013–1026.

Martins J, Gu Y, Marques D, Francisco H, Caramês J (2018) Differences on the Root and Root Canal Morphologies between Asian and White Ethnic Groups Analyzed by Cone-beam Computed Tomography. *Journal of endodontics* **44**(7), 1096–1104.

Martins J N R, Marques D, Silva E J N L, Caramês J, Mata A, Versiani M A (2019) Prevalence of C-shaped canal morphology using cone beam computed tomography – a systematic review with meta-analysis. *International Endodontic Journal* **52** (11), 1556–1572.

Martins J N R, Marques D, Silva E J N L, Caramês J, Versiani M A (2019) Prevalence Studies on Root Canal Anatomy Using Cone-beam Computed Tomographic Imaging: A Systematic Review. *Journal of Endodontics* **45**(4), 372-386.

Martins J N R, Kishen A, Marques D *et al.* (2020) Preferred Reporting Items for Epidemiologic Cross-sectional Studies on Root and Root Canal Anatomy Using Cone-beam Computed Tomographic Technology: A Systematized Assessment. *Journal of Endodontics* **46**(7), 915–935.

Martins J N R, Nole C, Ounsi H F *et al.* (2022) Worldwide Assessment of the Mandibular First Molar Second Distal Root and Root Canal: A Cross-sectional Study with Meta-analysis. *Journal of Endodontics* **48**(2), 223–233.

Mashyakhy M, Chourasia H R, Halboub E, Almashraqi A A, Khubrani Y, Gambarini G (2019) Anatomical variations and bilateral symmetry of roots and root canal system of mandibular first permanent molars in Saudi Arabian population utilizing cone- beam computed tomography. *Saudi Dental Journal* **31**(4), 481–486.

Miloglu O, Arslan H, Barutcigil C, Cantekin K (2013) Evaluating root and canal configuration of mandibular first molars with cone beam computed tomography in a Turkish population. *Journal of Dental Sciences* **8**(1), 80–86.

Munn Z, MClinSc S M, Lisy K, Riitano D, Tufanaru C (2015) Methodological guidance for systematic reviews of observational epidemiological studies reporting prevalence and cumulative incidence data. *International Journal of Evidence-Based Healthcare* **13**(3), 147–153.

Neelakantan P, Subbarao C, Subbarao C V (2010) Comparative evaluation of modified canal staining and clearing technique, cone-beam computed tomography, peripheral quantitative computed tomography, spiral computed tomography, and plain and contrast medium-enhanced digital radiography in studying root canal morphology. *Journal of Endodontics* **36**(9), 1547–1551.

Nur B G, Ok E, Altunsoy M, Aglarci O S, Colak M, Gungor E (2014) Evaluation of the root and canal morphology of mandibular permanent molars in a south-eastern Turkish population using cone-beam computed tomography. *European Journal of Dentistry* **8**(2), 154–159.

Omer O E, al Shalabi R M, Jennings M, Glennon J, Claffey N M (2004) A comparison between clearing and radiographic techniques in the study of the root-canal anatomy of maxillary first and second molars. *International endodontic journal*, **37**(5), 291–296.

Page M J, McKenzie J E, Bossuyt P M *et al.* (2021) The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ (Clinical research ed.)* **372**, 71.

Pan J Y Y, Parolia A, Chuah S R *et al.* (2019) Root canal morphology of permanent teeth in a Malaysian subpopulation using cone-beam computed tomography. *BMC Oral Health* **19,** 14.

Park J B, Kim N, Park S, Kim Y, Ko Y (2013) Evaluation of root anatomy of permanent mandibular premolars and molars in a Korean population with cone-beam computed tomography. *European journal of dentistry* **7**(1), 94–101.

Patel S, Wilson R, Dawood A, Mannocci F (2012) The detection of periapical pathosis using periapical radiography and cone beam computed tomography - Part 1: Pre-operative status. *International Endodontic Journal* **45**(8), 702–710.

Patil S R, Maragathavalli G, Araki K *et al.* (2018) Three-rooted mandibular first molars in a Saudi Arabian population: A CBCT study. *Pesquisa Brasileira Em Odontopediatria e Clinica Integrada* **18**(1), *4133*.

Pawar A M, Pawar M, Kfir A et al. (2017) Root canal morphology and variations in mandibular second molar teeth of an Indian population: an in vivo cone-beam computed tomography analysis. *Clinical oral investigations* **21**(9), 2801–2809.

Pérez-Heredia M, Ferrer-Luque C M, Bravo M, Castelo-Baz P, Ruíz-Piñón M, Baca P (2017) Cone-beam Computed Tomographic Study of Root Anatomy and Canal Configuration of Molars in a Spanish Population. *Journal of Endodontics* **43**(9), 1511–1516.

Pham K V, Le A (2019) Evaluation of Roots and Canal Systems of Mandibular First Molars in a Vietnamese Subpopulation Using Cone-Beam Computed Tomography. *Journal of International Society of Preventive & Community Dentistry* **9**(4), 356–362.

Poonam, Hans M K (2017) Prevalence of extra roots in mandibular first molars in north-western indian population aided with cone beam computed tomography. *Guident Endodontics.*

Qiao X, Zhu H, Yan Y *et al.* (2020) Prevalence of middle mesial canal and radix entomolaris of mandibular first permanent molars in a western Chinese population: An in vivo cone-beam computed tomographic study. *BMC Oral Health* **20**(1), 224.

Rivera J D S G (2013) Evaluación tomográfica de la configuración interna y anatomía externa en primeras molares inferiores permanentes de pacientes que acudieron al servicio de radiología oral y maxilofacial de la upch, lima 2013 – 2014 *(*Dissertation). Lima, Peru: Universidad Peruana Cayetano Heredia.

Riyahi A M, Alssum K, Hadadi H, Alsayyari A, Alebrah T, Aljarbou F (2019) Prevalence of three-rooted mandibular permanent first and second molars in the Saudi population. *Saudi Dental Journal* **31**(4), 492–495.

Sedentexct. (2011) Cone beam CT for dental and maxillofacial radiology (Evidence-based guidelines). *Protection Radiation*. URL www.sedentexct.eu [accessed on 21 February 2022]

Senan E M, Madfa A A, Alhadainy H A (2020) Root and canal configuration of mandibular first molars in a yemeni population: A cone-beam computed tomography. *European Endodontic Journal* **5**(3), 10–17.

Serene T P, Spolsky V W (1981) Frequency of endodontic therapy in a dental school setting. J*ournal of Endodontics* **7**(8), 385–387

Sharaan M E, Elrawdy A M (2017) An evaluation of mandibular molars root canal morphology using cone-beam computed tomography in an Egyptian subpopulation. *Tanta Dent Journal* **14**, 220-4.

Shemesh A, Levin A, Katzenell V *et al.* (2015) Prevalence of 3- and 4-rooted first and second mandibular molars in the Israeli population. *Journal of Endodontics* **41**(3), 338–342.

Sherrard J F, Rossouw P E, Benson B W, Carrillo R, Buschang P H (2010) Accuracy and reliability of tooth and root lengths measured on cone-beam computed tomographs. *American Journal of Orthodontics and Dentofacial Orthopedics* **137**(4 Suppl), 100–108.

Silva E J N L, Nejaim Y, Silva A V, Haiter-Neto F, Cohenca N (2013) Evaluation of root canal configuration of mandibular molars in a Brazilian population by using cone-beam computed tomography: An in vivo study. *Journal of Endodontics* **39**(7), 849–852.

Song J S, Choi H J, Jung I Y, Jung H S, Kim S O (2010) The Prevalence and Morphologic Classification of Distolingual Roots in the Mandibular Molars in a Korean Population. *Journal of Endodontics* **36**(4), 653–657.

Special Committee to Revise the Joint AAE/AAOMR Position Statement on use of CBCT in Endodontics (2015) AAE and AAOMR Joint Position Statement: Use of Cone Beam Computed Tomography in Endodontics 2015 Update. *Oral surgery, oral medicine, oral pathology and oral radiology* **120**(4), 508–512.

Torres A, Jacobs R, Lambrechts P *et al.* (2015) Characterization of mandibular molar root and canal morphology using cone beam computed tomography and its variability in Belgian and Chilean population samples. *Imaging Science in Dentistry* **45**(2), 95–101.

Tu M G, Huang H L, Hsue S *et al.* (2009) Detection of Permanent Three-rooted Mandibular First Molars by Cone-Beam Computed Tomography Imaging in Taiwanese Individuals. *Journal of Endodontics* **35**(4), 503–507.

Tu M G, Tsai C C, Jou M J (2007) Prevalence of Three-rooted Mandibular First Molars among Taiwanese Individuals. *Journal of Endodontics* **33**(10), 1163–1166.

Vertucci F J, Gainesville F (1884) Root canal anatomy of the human permanent teeth. *Oral surgery, oral medicine, and oral pathology* **58**(5), 589–599.

Wang Y, Zheng Q H, Zhou X D *et al.* (2010) Evaluation of the root and canal morphology of mandibular first permanent molars in a western chinese population by cone-beam computed tomography. *Journal of Endodontics* **36**(11), 1786–1789.

Wu D M, Wu Y N, Guo W, Sameer S (2006) Accuracy of direct digital radiography in the study of the root canal type. *Dentomaxillofacial Radiology* **35**(4), 263–265.

Yılmaz F, Kamburoglu K, Yeta N Y, Öztan M D (2016) Cone beam computed tomography aided diagnosis and treatment of endodontic cases: Critical analysis. *World Journal of Radiology* **8**(7), 716.

Zaatar E I, Ai-Kandari A M, Alhomaidah S, Yasin I M (1997) Frequency of endodontic treatment in Kuwait: radiographic evaluation of 846 endodontically treated teeth. *Journal of endodontics* **23**(7), 453–456.

Zadik Y, Sandler V, Bechor R, Salehrabi R (2008) Analysis of factors related to extraction of endodontically treated teeth. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontolog* **106**(5), 31–35.

Zhang R, Wang H, Tian Y Y, Yu X, Hu T, Dummer P M H (2011) Use of cone-beam computed tomography to evaluate root and canal morphology of mandibular molars in Chinese individuals. *International Endodontic Journal* **44**(11), 990–999.

Zhang X, Xiong S, Ma Y *et al.* (2015) A cone-beam computed tomographic study on mandibular first molars in a Chinese subpopulation. *PLoS ONE* **10**(8).

Zheng Q H, Zhou X D, Jiang Y. (2009). Radiographic investigation of frequency and degree of canal curvatures in Chinese mandibular permanent incisors. *Journal of endodontics* **35**(2), 175–178.

SUPPLEMENTARY TABLES

Supplemental Table S1 Terms and filters used in each electronic database

Database	Terms used	Filters
Pubmed	("endodontal"[All Fields] OR "endodontic"[All Fields] OR "endodontical"[All Fields] OR "endodontically"[All Fields] OR "endodontics"[MeSH Terms] OR "endodontics"[All Fields] OR ("plant roots"[MeSH Terms] OR ("plant"[All Fields] AND "roots"[All Fields]) OR "plant roots"[All Fields] OR "root"[All Fields]) OR "root canal"[All Fields] OR ("anatomy and histology"[MeSH Subheading] OR ("anatomy"[All Fields] AND "histology"[All Fields]) OR "anatomy and histology"[All Fields] OR "anatomy"[All Fields] OR "anatomy"[MeSH Terms] OR "anatomies"[All Fields]) OR ("anatomy and histology"[MeSH Subheading] OR ("anatomy"[All Fields] AND "histology"[All Fields]) OR "anatomy and histology"[All Fields] OR "morphology"[All Fields] OR "morphologies"[All Fields]) OR "root canal morphology"[All Fields] OR ("molar"[MeSH Terms] OR "molar"[All Fields] OR "molars"[All Fields] OR "molar s"[All Fields] OR "mandibular molar"[All Fields] OR "mandibular first molar"[All Fields] OR "posterior teeth"[All Fields])) AND ("plant roots"[MeSH Terms] OR ("plant"[All Fields] AND "roots"[All Fields]) OR "plant roots"[All Fields] OR "radix"[All Fields] OR "radixes"[All Fields] OR "radix entomolaris"[All Fields] OR "radix paramolaris"[All Fields] OR "distolingual root"[All Fields] OR "additional root"[All Fields] OR "supernumerary root"[All Fields] OR "three rooted"[All Fields]) AND ("cone-beam computed tomography"[All Fields] OR "cone-beam CT"[All Fields] OR "CBCT"[All Fields])	N/F
Scopus	(endodontics OR root OR "root canal" OR anatomy OR morphology OR "root canal morphology") AND (molar OR "mandibular molar" OR "mandibular first molar" OR "posterior teeth") AND (radix OR "radix entomolaris" OR "radix molaris" OR "radix paramolaris" OR "distolingual root" OR "additional root" OR "supernumerary root" OR "three rooted") AND ("cone-beam computed tomography" OR "cone beam CT" OR "CBCT")	N/F
LILACS	endodontics AND radix OR “additional root”	N/F
Science Direct	endodontics AND (radix OR "additional root" OR "supernumerary root" OR "three rooted") AND ("CBCT" OR "Cone beam computed tomography")	N/F

Embase	'endodontics'/exp OR endodontics AND 'cone beam computed tomography' AND radix OR 'additional root' OR 'supernumerary root' OR 'three rooted'	N/F
Web of Science	((((ALL=(radix)) OR ALL=("additional root")) OR ALL=("supernumerary root")) OR ALL=("three rooted")) AND ALL=(endodontics)	N/F
Cochrane Collaboration	endodontics in All Text AND radix in All Text OR "additional root" in All Text OR "three rooted" in Title Abstract Keyword OR "supernumerary root" in Title Abstract Keyword - (Word variations have been searched)	N/F
Open Grey	endodontics	N/F
Google Scholar	endodontics AND "additional root" AND "cone-beam computed tomography"	N/F

N/F: No filter

Supplemental Table S2 Inclusion and exclusion criteria

Inclusion
Evaluation under CBCT
In vivo study
Human study
First and/or second permanent mandibular molars
Sample size (teeth) is given
Country is given
The prevalence of additional root is given or can be calculated
JBI Critical Appraisal equal or greater than 50%
Articles in English, Portuguese and Spanish
Exclusion
Review studies
Case report
Sample has been partially analyzed in another included study

Supplemental Table S3 Reliability between evaluators for each question of the Joanna Briggs Institute (JBI) Critical Appraisal tool for systematic reviews of prevalence studies questions

#	JBI Question
1	Was the sample frame appropriate to address the target population?
2	Were study participants recruited in an appropriate way?
3	Was the sample size adequate?
4	Were the study subjects and setting described in detail?
5	Was 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?

* No statistic was calculated because Observer B values were constant

Supplemental Table S4 List of the studies excluded from the review

Number of study	Study	Reason
1	Aguero S M (2020)	JBI Critical Appraisal inferior to 50%
2	Al Shehadat S *et al.* (2019)	JBI Critical Appraisal inferior to 50%
3	Alswilem R *et al.* (2018)	No additional roots prevalence is given
4	Caputo B V *et al.* (2016)	JBI Critical Appraisal inferior to 50%
5	Chen L *et al.* (2014)	It is not included in the language restriction (Chinese)
6	Choi M R *et al.* (2015)	It does not give the individual prevalence of first and second molars
7	Deng P U *et al.* (2018)	Data is unclear
8	Donyavi Z *et al.* (2019)	JBI Critical Appraisal inferior to 50%
9	Felsypremila G *et al.* (2015)	JBI Critical Appraisal inferior to 50%
10	Huang R Y *et al.* (2010)	It is not a CBCT study (use of multislice spiral CT)
11	Jang J H *et al.* (2018)	It is not included in the language restriction (Korean)
12	Kim S *et al.* (2012)	Only evaluated if the additional root was clearly separated and is not a prevalence study
13	LIU X *et al.* (2012)	It is not included in the language restriction (Chinese)
14	Ma H F *et al.* (2017)	It is not included in the language restriction (Chinese)
15	Madani Z S *et al.* (2017)	JBI Critical Appraisal inferior to 50%
16	Mendes M J P (2017)	It does not give the individual prevalence of first and second molars
17	Nur B G *et al.* (2014)	JBI Critical Appraisal inferior to 50%
18	Patil S R *et al.* (2018)	JBI Critical Appraisal inferior to 50%
19	Pekiner F N *et al.* (2017)	Data is unclear

20	Plotino G *et al.* (2013)	It is not a prevalence study
21	Przesmycka, A., 2020	Use of dental material from archeological sites
22	Rahimi S *et al.* (2017)	Sample is the patient, not the tooth
23	Rodrigues C T *et al.* (2016)	JBI Critical Appraisal inferior to 50%
24	Ruiz Arreaga, Ingrid Anaité, 2015	JBI Critical Appraisal inferior to 50%
25	Štamfelj I (2021)	Letter to the editor
26	Tocci L *et al.* (2013)	It is not included in the language restriction (Italian)
27	Tredoux S *et al.* (2021)	JBI Critical Appraisal inferior to 50%
28	Wu Y C *et al.* (2017)	Is not a prevalence study
29	Wu Y C *et al.* (2018)	Is not a prevalence study
30	Wu Y C *et al.* (2018)	Is not a prevalence study
31	Wu Y C *et al.* (2018)	Is not a prevalence study
32	Wu Y C *et al.* (2018)	Is not a prevalence study
33	Wu Y C *et al.* (2020)	Is not a prevalence study

1. Agüero S M (2020) Prevalencia de radix entomolaris en primeros molares inferiores permanentes y conductos en forma de “c” en segundos molares inferiores permanentes por medio de la tomografía computarizada de haz cónico en el centro de diagnóstico por imágenes el galeno en tacna - perú, 2017. (Specialization Final paper). Tacna, Peru: Universidad Privada de Tacna.
2. al Shehadat S, Waheb S, al Bayatti S W, Kheder W, Khalaf K, Murray C A (2019) Cone beam computed tomography analysis of root and root canal morphology of first permanent lower molars in a Middle East subpopulation. *Journal of International Society of Preventive and Community Dentistry* **9**(5), 458–463.
3. Alswilem R, Abouonq A, Iqbal A, Alajlan S S, Alam M K (2018) Three-dimensional cone-beam computed tomography assessment of additional canals of permanent first molars: A Pinocchio for successful root canal treatment. *Journal of International Society of Preventive and Community Dentistry* **8**(3), 259–263.
4. Arreaga I A R (2015) Uso de la tomografía computarizada de haz cónico para evaluar la morfología de la raíz y el conducto radicular de los primeros y segundos molares inferiores en pacientes de la facultad de odontología de la universidad san carlos de guatemala. (Final paper). Guatemala: Facultad de Odontología de la Universidad de San Carlos de Guatemala.
5. Caputo B V, Noro Filho G A, de Andrade Salgado D M R, Moura-Netto C, Giovani E M, Costa C (2016) Evaluation of the Root Canal Morphology of Molars by Using Cone-beam Computed Tomography in a Brazilian Population: Part I. *Journal of Endodontics* **42**(11), 1604–1607.
6. Choi M R, Moon Y M, Seo M S (2015) Prevalence and features of distolingual roots in mandibular molars analyzed by cone-beam computed tomography. *Imaging Science in Dentistry* **45**(4), 221–226.

7. Chen L, Chen J G, Gu Y C (2014) Detection of root variations of permanent mandibular first and second molars by cone-beam computed tomography. *Shanghai journal of stomatology* **23**(2), 224–228.
8. Deng P U, Halim M S, Masudi S M, Al-Shehadat S, Ahmad B (2018) Cone-beam computed tomography analysis on root and canal morphology of mandibular first permanent molar among multiracial population in East Coast Malaysian population. *European Journal of Dentistry* **12**(3), 410–416.
9. Donyavi Z, Shokri A, Khoshbin E, Khalili M, Faradmal J (2019) Assessment of root canal morphology of maxillary and mandibular second molars in the iranian population using CBCT. *Dental and Medical Problems* **56**(1), 45–51.
10. Felsypremila G, Vinothkumar T S, Kandaswamy D (2015) Anatomic symmetry of root and root canal morphology of posterior teeth in Indian subpopulation using cone beam computed tomography: A retrospective study. *European Journal of Dentistry* **9**(4), 500–507.
11. Huang C C, Chang Y C, Chuang M C, Lai T M, Lai J Y, Lee B S, Lin C P (2010) Evaluation of Root and Canal Systems of Mandibular First Molars in Taiwanese Individuals Using Cone-beam Computed Tomography. *Journal of the Formosan Medical Association* **109**(4), 303–308.
12. Jang J-H, Kim J-W, Cho K-M, Kim S-Y, Park S-H (2018) A study on Radix Entomolaris about prevalence and correlation of canal orifices location according to number of roots in mandibular first molars. *The Journal of the Korean dental association* **56**(12), 695-706.
13. Kim S, Choi M R, Yoo J J (2013) Concurrent relationship between additional canals of mandibular first molars and maxillary first molars using cone-beam computed tomography. *Oral Radiology* **29**(2), 146–150.
14. Liu X, Yang B, Hao J *et al.* (2012) Evaluation of the number of roots and canals of mandibular first permanent molars in a northwestern Chinese population by cone-beam computed tomography.
15. Ma H, Geng H, Qian J, Liu H, Liu P (2017) Variations in the root and root canal of permanent mandibular first molars in the han population of southwest shandong province: a three-dimensional reconstruction based on cone-beam CT data using planmeca romexis software. *Chinese Journal of Tissue Engineering Research* **21**(16).
16. Madani Z S, Mehraban N, Moudi E, Bijani A (2017) Root and canal morphology of mandibular molars in a selected iranian population using cone-beam computed tomography. *Iranian Endodontic Journal* **12**(2), 143–148.
17. Mendes M J P (2017) Prevalência de "radix entomolaris" numa amostra da população portuguesa: avaliação com cbct. (Dissertation). Coimbra: Faculdade de Medicina da Universidade de Coimbra.
18. Nur B G, Ok E, Altunsoy M, Aglarci O S, Colak M, Gungor E (2014) Evaluation of the root and canal morphology of mandibular permanent molars in a south-eastern Turkish population using cone-beam computed tomography. *European Journal of Dentistry* **8**(2), 154–159.
19. Patil S R, Maragathavalli G, Araki K, Al-Zoubi I A, Sghaireen M G, Gudipaneni R K, Alam M K (2018) Three-rooted mandibular first molars in a Saudi Arabian population: A CBCT study. *Pesquisa Brasileira Em Odontopediatria e Clinica Integrada* **18**(1).

20. Pekiner F N, Borahan M O, Dumlu A (2017) Evaluation of Distolingual Canal/Roots in Mandibular Molars and Mesiobuccal Canals in Maxillary Molars by CBCT. *The Open Dentistry Journal* **11**(1), 360–366.
21. Plotino G, Tocci L, Grande N M *et al.* (2013) Symmetry of root and root canal morphology of maxillary and mandibular molars in a white population: A cone-beam computed tomography study in vivo. *Journal of Endodontics* **39**(12), 1545–1548.
22. Przesmycka A, Jędrychowska-Dańska K, Masłowska A, Witas H, Regulski P, Tomczyk J (2020) Root and root canal diversity in human permanent maxillary first premolars and upper/lower first molars from a 14th-17th and 18th-19th century Radom population. *Archives of oral biology* ***110*,** 104603.
23. Rahimi S, Mokhtari H, Ranjkesh B *et al.* (2017). Prevalence of extra roots in permanent mandibular first molars in Iranian population: A CBCT analysis. *Iranian Endodontic Journal* **12**(1), 25–28.
24. Rodrigues C T, de Oliveira-Santos C, Bernardineli N *et al.* (2016) Prevalence and morphometric analysis of three-rooted mandibular first molars in a Brazilian subpopulation. *Journal of Applied Oral Science* **24**(5), 535–542.
25. Štamfelj I (2021) Evaluation of radix entomolaris in mandibular first and second molars using cone-beam computed tomography and a review of the literature. In *Oral Radiology* **37**(3), 543–545.
26. Tocci L, Plotino G, Grande N M *et al.* (2013) Analysis of root and root canal morphology of maxillary and mandibular molars in a Caucasian population: CBCT study in vivo. *Giornale Italiano di Endodonzia* **27** (1), 13-20.
27. Tredoux S, Warren N, Buchanan G D (2021) Root and canal configurations of mandibular first molars in a south african subpopulation. *Journal of Oral Science* **63**(3), 252–256.
28. Wu Y C, Cheng W C, Chung M P *et al.* (2017) Complicated Root Canal Morphology of Mandibular Lateral Incisors Is Associated with the Presence of Distolingual Root in Mandibular First Molars: A Cone-beam Computed Tomographic Study in a Taiwanese Population. *Journal of endodontics* **44**(1), 73–79.
29. Wu Y C, Cathy Tsai Y W, Cheng W C *et al.* (2018) Relationship of the Incidence of C-shaped Root Canal Configurations of Mandibular First Premolars with Distolingual Roots in Mandibular First Molars in a Taiwanese Population: A Cone-beam Computed Tomographic Study. *Journal of Endodontics* **44**(10), 1492-1499.
30. Wu Y C, Cheng W C, Chung M P *et al.* (2018a) Complicated Root Canal Morphology of Mandibular Lateral Incisors Is Associated with the Presence of Distolingual Root in Mandibular First Molars: A Cone-beam Computed Tomographic Study in a Taiwanese Population. *Journal of Endodontics* **44**(1), 73-79.
31. Wu Y C, Cheng W C, Chung M P *et al.* (2018b) Complicated Root Canal Morphology of Mandibular Lateral Incisors Is Associated with the Presence of Distolingual Root in Mandibular First Molars: A Cone-beam Computed Tomographic Study in a Taiwanese Population. *Journal of Endodontics* **44**(1), 73-79.
32. Wu Y C, Su W S, Mau L P *et al.* (2020) Association between the presence of distolingual root in mandibular first molars and the presence of C-shaped mandibular second molars: a CBCT study in a Taiwanese population. *Quintessence international (Berlin, Germany: 1985)* **51**(10), 798–807.
33. Wu Y C, Cheng W C, Weng P W *et al.* (2018) The Presence of Distolingual Root in Mandibular First Molars Is Correlated with Complicated Root Canal Morphology of

Mandibular Central Incisors: A Cone-beam Computed Tomographic Study in a Taiwanese Population. *Journal of Endodontics* **44**(5), 711-716.

Supplemental Table S5 Prevalence of additional root in each country according to the division of continents and their respective averages

America	**4.7%**		**Min-max (1.7 - 6.8)**
		Peru	6.8
		Venezuela	2.6
		Brazil	1.7
		Chile	5.4
Europe	**2.9%**		**(2 - 4.3)**
		Grecce	4.3
		Portugal	2.5
		Spain	2
		Belgium	2.3
Middle East	**2.7%**		**(0.2 - 4.5)**
		Egypt	0.2
		Saudi Arabia	4.5
		Turkey	2
		Cyprus	2.1
		Iran	3.2
		Yemen	3.2
		Israel	2.4
East Asia	**19.7%**		**(19 - 25.4)**
		China	21.6
		Taiwan	25.4
		Korea	19
South and Southeast Asia	**6.1%**		**(4.1 - 12.3)**
		India	4.1
		Thailand	7.5
		Malaysia	10.8
		Vietnam	12.3

4 CONSIDERAÇÕES FINAIS

A presente revisão sistemática com meta-análise teve como objetivo principal avaliar a prevalência de raiz adicional em primeiros e segundos molares inferiores através de estudos transversais que utilizaram a TCFC como método de imagem. Esse questionamento surgiu a partir da importância do conhecimento da anatomia dentária e suas anormalidades, buscando a limpeza de todo o sistema de canais radiculares, visando o sucesso endodôntico.

Esse estudo seguiu os protocolos do PRISMA e possui registro prévio no PROSPERO, caracterizando sua transparência, e incluiu um número amostral de 38.533 dentes. Além disso, as análises em subgrupos realizadas, como a localização da raiz adicional, o gênero e o tipo de dente, permitiram uma visão mais detalhada da prevalência. Bem como, a avaliação pela localização geográfica, que demonstrou interferência étnica na prevalência de raiz adicional, principalmente no Leste da Ásia.

A prevalência global de raiz adicional foi de 10,3%, sendo mais prevalente em primeiros molares. Para os dois tipos dentários, RE apresentou maior número de casos comparado ao RP. Ambos radix, foram mais comumente encontrados em primeiros molares. Nos primeiros molares, os homens possuíram uma maior chance de apresentar raiz adicional comparado às mulheres. Não houve diferença estatística entre gêneros para os segundos molares. Nos casos onde a localização da raiz não foi especificada, não houve diferença estatística, nem para o tipo dentário, nem para o gênero.

Essa revisão sistemática também avaliou a qualidade metodológica e o risco de viés dos estudos incluídos de acordo com a ferramenta Joanna Briggs Institute (JBI) Critical Appraisal, associada ao guideline para reportar estudos de prevalência utilizando TCFC, para uma melhor avaliação dos estudos. Diante dos resultados, os estudos incluídos apresentaram baixo risco de viés, confirmado através do teste de Egger, porém, alta heterogeneidade, relacionada ao grande número de amostras, sem comprometer os resultados do estudo.

Dessa forma, essa revisão sistemática evidencia as localizações, tipos dentários e gêneros mais acometidos para cada raiz adicional, auxiliando no conhecimento da anatomia dentária e as chances de encontrar um raiz e canal adicional, auxiliando no melhor resultado da terapia endodôntica.

REFERÊNCIAS

AAE/AAOMR. AAE and AAOMR Joint Position Statement: Use of Cone Beam Computed Tomography in Endodontics—2015/2016 Update. **Oral surgery, oral medicine, oral pathology and oral radiology**, v. **120**, n. 4, p. 508–512, 2015.

ABELLA, F. et al. Managing severe curvature of radix entomolaris: Three-dimensional analysis with cone beam computed tomography. **International Endodontic Journal**, v. 44, n. 9, p. 876–885, set. 2011.

AGARWAL, M. et al. The radix entomolaris and radix paramolaris: An endodontic challenge. **Journal of Contemporary Dental Practice**, v. 15, n. 4, p. 496–499, 2015.

AL-ALAWI, H. et al. The prevalence of radix molaris in the mandibular first molars of a Saudi subpopulation based on cone-beam computed tomography. **Restorative Dentistry & Endodontics**, v. 45, n. 1, 2020.

ALENEZI, K.; ALHARBI, B.; KOLARKODI, S. Prevalence of three rooted mandibular permanent first molars in Qassim population in Saudi Arabia. **International Journal of Medicine in Developing Countries**, p. 1797–1800, 2020.

ALVAREZ C N; ALVARADO L D. Evaluación tomográfica radicular de molares mandibulares. 2018. Disertación (Maestría en Odontología) – Universidad Inca Garcilaso de la Veja, Lima, Peru, 2018.

BARUWA, A. O. et al. The Influence of Missed Canals on the Prevalence of Periapical Lesions in Endodontically Treated Teeth: A Cross-sectional Study. **Journal of Endodontics**, v. 46, n. 1, p. 34- 39.e1, 1 jan. 2020.

CALBERSON, F. L.; DE MOOR, R. J.; DEROOSE, C. A. The Radix Entomolaris and Paramolaris: Clinical Approach in Endodontics. **Journal of Endodontics**, v. 33, n. 1, p. 58–63, jan. 2007.

CANTATORE, G.; BERUTTI, E.; CASTELLUCCI, A. Missed anatomy: frequency and clinical impact. **Endodontic Topics 2009**, v. 15, p. 3–31, 2006.

CARLSEN, O.; ALEXANDERSEN, V.; CARLSEN, O. Radix entomolaris: identification and morphology. **Department of Denial Morphology, Royal Denial College, Copenhagen, Denmark,** v. 98, p. 363-73, 1990.

CARLSEN, O.; ALEXANDERSEN, V.; CARLSEN, O. Radix paramolaris in permanent mandibular molars: identification and morphology. **Department of Denial Morphology, Royal Denial College, Copenhagen, Denmark,** v. 99, p. 189-95, 1991.

CELIKTEN, B. et al. Cone beam CT evaluation of mandibular molar root canal morphology in a Turkish Cypriot population. **Clinical Oral Investigations**, v. 20, n. 8, p. 2221–2226, 1 nov. 2016.

CHEN, G.; YAO, H.; TONG, C. Investigation of the root canal configuration of mandibular first molars in a Taiwan Chinese population. **International Endodontic Journal**, v. 42, n. 11, p. 1044–1049, nov. 2009.

COSTA, F. F. N. P. et al. Association between missed canals and apical periodontitis. **International Endodontic Journal**, v. 52, n. 4, p. 400–406, 1 abr. 2019.

COTTON, T. P. et al. Endodontic Applications of Cone-Beam Volumetric Tomography. **Journal of Endodontics**, v. 33, n 9, p. 1121–1132, set. 2007.

CURZON, M. E. Miscegenation and the prevalence of three-rooted mandibular first molars in the Baffin Eskimo. **Community Dent Oral Epidemiol**, v. 2, n. 3, p. 130-131, 1974.

DE MOOR, R. J. G.; DEROOSE, C. A. J. G.; CALBERSON, F. L. G. The radix entomolaris in mandibular first molars: an endodontic challenge. **International Endodontic Journal**. v. 37, n. 11, p. 789–799, 2004.

DE PABLO, Ó. V. et al. Root anatomy and canal configuration of the permanent mandibular first molar: A systematic review. **Journal of Endodontics,** v. 36, n. 12, p. 1919–1931, 2010.

DE SOUZA-FREITAS, J. A.; LOPES, E. S.; CASATI-ALVARES, L. Anatomic variations of lower first permanent molar roots in two ethnic groups. **Oral surgery, oral medicine, and oral pathology,** v. 31, n. 2, p. 274–278, 1971.

DEMIRBUGA, S. et al. Use of cone-beam computed tomography to evaluate root and canal morphology of mandibular first and second molars in Turkish individuals. **Medicina Oral, Patologia Oral y Cirugia Bucal**, v. 18, n. 4, 1 jul. 2013.

DENG, P. U. et al. Cone-beam computed tomography analysis on root and canal morphology of mandibular first permanent molar among multiracial population in East Coast Malaysian population. **European Journal of Dentistry**, v. 12, n. 3, p. 410–416, 1 jul. 2018.

DUMAN, S. B. et al. Evaluation of radix entomolaris in mandibular first and second molars using cone-beam computed tomography and review of the literature. **Oral Radiology**, v. 36, n. 4, p. 320–326, 1 out. 2020.

DURACK, C.; PATEL, S. Cone Beam Computed Tomography in Endodontics. **Brazilian dental journal,** v. 23, n. 3, p. 179–191, 2012.

FELSYPREMILA, G.; VINOTHKUMAR, T. S.; KANDASWAMY, D. Anatomic symmetry of root and root canal morphology of posterior teeth in Indian subpopulation using cone beam computed tomography: A retrospective study. **European Journal of Dentistry**, v. 9, n. 4, p. 500–507, 2015.

GASTELÚ, E. R. D. A. **Características morfológicas de radix entomolaris en molares inferiores evaluadas mediante tomografía cone beam en pacientes del hospital de policía nacional luis nicasio sáenz 2017.** 2019. (Disertación (Maestría en Odontología) – Universidad Nacional Federico Villarreal, Lima, Peru, 2019.

GOMEZ, F.; BREA, G.; GOMEZ-SOSA, J. F. Root canal morphology and variations in mandibular second molars: an in vivo cone-beam computed tomography analysis. **BMC Oral Health**, v. 21, n. 1, 1 dez. 2021.

HIGGINS, J. P. T.; THOMPSON, S. G. Quantifying heterogeneity in a meta-analysis. **Statistics in Medicine**, v. 21, n. 11, p. 1539–1558, 15 jun. 2002.

HIRAN-US, S. et al. Prevalence of C-shaped Canals and Three-rooted Mandibular Molars Using CBCT in a Selected Thai Population. **Iranian Endodontic Journal,** v. 16, n. 2, p. 97-102, 2021.

HOEN, M. M.; PINK, F. E. Contemporary Endodontic Retreatments: An Analysis based on Clinical Treatment Findings**. Journal of endodontics**, v. 28, n. 12, p. 834–836, 2002.

HOPEWELL, S. et al. Incorporation of assessments of risk of bias of primary studies in systematic reviews of randomised trials: a cross-sectional study. **BMJ open,** v. 3, n. 8, e003342, 2013.

HOSSEINI, S. et al. Frequency of middle mesial canal and radix entomolaris in mandibular first molars by cone beam computed tomography in a selected Iranian population. **Caspian J Dent Res**, v. 9, p. 63-70, 2020.

HUANG, C. C. et al. Evaluation of Root and Canal Systems of Mandibular First Molars in Taiwanese Individuals Using Cone-beam Computed Tomography. **Journal of the Formosan Medical Association**, v. 109, n. 4, p. 303–308, abr. 2010.

JAMSHIDI, D. et al. Evaluation of the association between the number and configuration of root canals of mandibular molars in an Iranian subpopulation: A cone-beam computed tomography study. **Saudi Endodontic Journal**, v. 11, n. 1, p. 93–99, 1 jan. 2021.

JANG, J. K. et al. Incidence of three roots and/or four root canals in the permanent mandibular first molars in a Korean sub-population. **Clinical Oral Investigations**, v. 17, n. 1, p. 105–111, 1 jan. 2013.

KANTILIERAKI, E. et al. Evaluation of root and root canal morphology of mandibular first and second molars in a Greek population: A CBCT study. **European Endodontic Journal**, v. 4, n. 2, p. 62–68, 2019.

KIM, H.-H. et al. CBCT study of mandibular first molars with a distolingual root in Koreans. **Restorative Dentistry & Endodontics**, v. 43, n. 3, 2018a.

KIM, S.; CHOI, M. R.; YOO, J. J. **Concurrent relationship between additional canals of mandibular first molars and maxillary first molars using cone-beam computed tomography**. Oral Radiology. **Anais**...jul. 2013.

KIM, S. Y. et al. Morphology of mandibular first molars analyzed by cone-beam computed tomography in a korean population: Variations in the number of roots and canals. **Journal of Endodontics**, v. 39, n. 12, p. 1516–1521, dez. 2013.

KIM, S. Y.; KIM, B. S.; KIM, Y. Mandibular second molar root canal morphology and variants in a Korean subpopulation. **International Endodontic Journal**, v. 49, n. 2, p. 136–144, 1 fev. 2016.

KIM, S. Y.; YANG, S. E. Cone-beam computed tomography study of incidence of distolingual root and distance from distolingual canal to buccal cortical bone of mandibular first molars in a korean population. **Journal of Endodontics**, v. 38, n. 3, p. 301–304, mar. 2012.

KIM, Y. et al. Morphological Characteristics and Classification of Mandibular First Molars Having 2 Distal Roots or Canals: 3-Dimensional Biometric Analysis Using Cone-beam Computed Tomography in a Korean Population. **Journal of Endodontics**, v. 44, n. 1, p. 46–50, 1 jan. 2018b.

KRISHNAMURTHY, N. H. et al. Anatomical configuration of roots and canal morphology of primary mandibular first molars: A CBCT study. **Journal of Clinical and Diagnostic Research**, v. 11, n. 11, p. ZC09-ZC11, 1 nov. 2017.

LOH, H. S. Incidence and features of three-rooted permanent mandibular molars. **Australian Dental Journal**, v. 35, n. 5, p. 434–437, 1990.

MADANI, Z. S. et al. Root and canal morphology of mandibular molars in a selected iranian population using cone-beam computed tomography. **Iranian Endodontic Journal**, v. 12, n. 2, p. 143–148, 1 mar. 2017.

MAGNUCKI, G.; MIETLING, S. V. K. Four-Rooted Maxillary First Molars: A Systematic Review and Meta-Analysis. **International Journal of Dentistry**, 20 jan, 2021.

MARTINS, J. N. R. et al. Root and root canal morphology of the permanent dentition in a Caucasian population: a cone-beam computed tomography study. **International Endodontic Journal**, v. 50, n. 11, p. 1013–1026, 1 nov. 2017.

MARTINS, J. N. R. et al. Differences on the Root and Root Canal Morphologies between Asian and White Ethnic Groups Analyzed by Cone-beam Computed Tomography. **Journal of Endodontics**, v. 44, n. 7, p. 1096–1104, 1 jul. 2018.

MARTINS, J. N. R. et al. Prevalence Studies on Root Canal Anatomy Using Cone-beam Computed Tomographic Imaging: A Systematic Review. **Journal of Endodontics**, v. 45, n. 4, p. 372-386, 1 abr. 2019a.

MARTINS, J. N. R. et al. Prevalence of C-shaped canal morphology using cone beam computed tomography – a systematic review with meta-analysis. **International Endodontic Journal**, v. 52, n. 11, p. 1556-1572, 1 nov. 2019b.

MARTINS, J. N. R. et al. Preferred Reporting Items for Epidemiologic Cross-sectional Studies on Root and Root Canal Anatomy Using Cone-beam Computed Tomographic Technology: A Systematized Assessment. **Journal of Endodontics**, v. 46, n. 7, p. 915-935, 1 jul. 2020.

MARTINS, J. N. R. et al. Worldwide Assessment of the Mandibular First Molar Second Distal Root and Root Canal: A Cross-sectional Study with Meta-analysis. **Journal of Endodontics**, v. 48, n. 2, p. 223–233, 1 fev. 2022.

MASHYAKHY, M. et al. Anatomical variations and bilateral symmetry of roots and root canal system of mandibular first permanent molars in Saudi Arabian population utilizing cone- beam computed tomography. **Saudi Dental Journal**, v. 31, n. 4, p. 481–486, 1 out. 2019.

MILOGLU, O. et al. Evaluating root and canal configuration of mandibular first molars with cone beam computed tomography in a Turkish population. **Journal of Dental Sciences**, v. 8, n. 1, p. 80–86, mar. 2013.

MUNN, Z. et al. Methodological guidance for systematic reviews of observational epidemiological studies reporting prevalence and cumulative incidence data. **International Journal of Evidence-Based Healthcare**, v. 13, n. 3, p. 147–153, 1 set. 2015.

NAIR, M. K.; NAIR, U. P. Digital and Advanced Imaging in Endodontics: A Review. **Journal of Endodontics**, v. 33, n. 1, p. 1–6, jan. 2007.

NEELAKANTAN, P.; SUBBARAO, C.; SUBBARAO, C. V. Comparative evaluation of modified canal staining and clearing technique, cone-beam computed tomography, peripheral quantitative computed tomography, spiral computed tomography, and plain and contrast medium-enhanced digital radiography in studying root canal morphology. **Journal of Endodontics**, v. 36, n. 9, p. 1547–1551, 2010.

NUR, B. G. et al. Evaluation of the root and canal morphology of mandibular permanent molars in a south-eastern Turkish population using cone-beam computed tomography. **European Journal of Dentistry**, v. 8, n. 2, p. 154–159, 2014.

OMER, O. E. et al. **A comparison between clearing and radiographic techniques in the study of the root-canal anatomy of maxillary first and second molars**. [s.l: s.n.].

PAGE, M. J. et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. **British Medical Journal**, v. 372, n. 71, 29 mar. 2021.

PAN, J. Y. Y. et al. Root canal morphology of permanent teeth in a Malaysian subpopulation using cone-beam computed tomography. **BMC Oral Health**, v. 19, n. 1, 14 jan. 2019.

PARK, J.-B. et al. European Journal of Dentistry Evaluation of root anatomy of permanent mandibular premolars and molars in a Korean population with cone-beam computed tomography. **European journal of dentistry**, v. *7*, n. 1, p. 94–101, 2013.

PATEL, S. et al. The detection of periapical pathosis using periapical radiography and cone beam computed tomography - Part 1: Pre-operative status. **International Endodontic Journal**, v. 45, n. 8, p. 702–710, ago. 2012.

PATIL, S. R. et al. Three-rooted mandibular first molars in a Saudi Arabian population: A CBCT study. **Pesquisa Brasileira em Odontopediatria e Clinica Integrada**, v. 18, n. 1, 27 ago. 2018.

PAWAR, A. M. et al. Root canal morphology and variations in mandibular second molar teeth of an Indian population: an in vivo cone-beam computed tomography analysis. **Clinical Oral Investigations**, v. 21, n. 9, p. 2801–2809, 1 dez. 2017.

PÉREZ-HEREDIA, M. et al. Cone-beam Computed Tomographic Study of Root Anatomy and Canal Configuration of Molars in a Spanish Population. **Journal of Endodontics**, v. 43, n. 9, p. 1511–1516, 1 set. 2017.

PHAM, K. VAN; LE, A. H. L. Evaluation of Roots and Canal Systems of Mandibular First Molars in a Vietnamese Subpopulation Using Cone-Beam Computed Tomography. **Journal of International Society of Preventive & Community Dentistry**, v. 9, n. 4, p. 356–362, 2019.

POONAM; HANS, M. K. Prevalence of extra roots in mandibular first molars in north-western indian population aided with cone beam computed tomography. **Guident,** 2017.

QIAO, X. et al. Prevalence of middle mesial canal and radix entomolaris of mandibular first permanent molars in a western Chinese population: An in vivo cone-beam computed tomographic study. **BMC Oral Health**, v. 20, n. 1, 17 ago. 2020.

RAHIMI, S. et al. Prevalence of extra roots in permanent mandibular first molars in Iranian population: A CBCT analysis. **Iranian Endodontic Journal**, v. 12, n. 1, p. 25–28, 1 dez. 2017.

RIVERA, J. D. S. G. **Evaluación tomográfica de la configuración interna y anatomía externa en primeras molares inferiores permanentes de pacientes que acudieron al servicio de radiología oral y maxilofacial de la upch, lima 2013 - 2014.** 2019. (Disertación (Maestría en Odontología) – Universidad Peruana Cayetano Heredia, Lima, Peru, 2019.

RIYAHI, A. M. et al. Prevalence of three-rooted mandibular permanent first and second molars in the Saudi population. **Saudi Dental Journal**, v. 31, n. 4, p. 492–495, 1 out. 2019.

SARANGI, P.; UPPIN, V. M.; SARANGI, P. Mandibular First Molar with a Radix Entomolaris: An Endodontic Dilemma. **Journal of Dentistry**, v. 11, n. 1, p. 118-122, 2014.

SEDENTEXCT. Cone beam CT for dental and maxillofacial radiology (Evidence-based guidelines). **Protection Radiation**, 2011.

SENAN, E. M.; MADFA, A. A.; ALHADAINY, H. A. Root and canal configuration of mandibular first molars in a yemeni population: A cone-beam computed tomography. **European Endodontic Journal**, v. 5, n. 3, p. 10–17, 2020.

SERENE, T. P.; SPOLSKY, V. W. Frequency of endodontic therapy in a dental school setting. **Journal of endodontics**, v. 7, n. 8, p. 385–387, 1981.

SHARAAN, M.; ELRAWDY, A. An evaluation of mandibular molars root canal morphology using cone-beam computed tomography in an Egyptian subpopulation. **Tanta Dental Journal**, v. 14, n. 4, p. 220, 2017.

SHEMESH, A. et al. Prevalence of 3- and 4-rooted first and second mandibular molars in the Israeli population. **Journal of Endodontics**, v. 41, n. 3, p. 338–342, 1 mar. 2015.

SHERRARD, J. F. et al. Accuracy and reliability of tooth and root lengths measured on cone-beam computed tomographs. **American Journal of Orthodontics and Dentofacial Orthopedics**, v. 137, n. 4 SUPPL., abr. 2010.

SILVA, E. J. N. L. et al. Evaluation of root canal configuration of mandibular molars in a Brazilian population by using cone-beam computed tomography: An in vivo study. **Journal of Endodontics**, v. 39, n. 7, p. 849–852, jul. 2013.

SONG, J. S. et al. The Prevalence and Morphologic Classification of Distolingual Roots in the Mandibular Molars in a Korean Population. **Journal of Endodontics**, v. 36, n. 4, p. 653–657, abr. 2010.

SPERBER, G. H.; MOREAU, J. L. Study of the number of roots and canals in Senegalese first permanent mandibular molars. **International endodontic journal**, v. 31, n. 2, p. 117–122, 1998.

TACHIBANA, H.; MATSTJMOTO, K. X-ray computerized tomography in endodontics. **Endodontics & dental traumatology**, v. 6, n. 1, p. 16–20, 1990.

TORRES, A. et al. Characterization of mandibular molar root and canal morphology using cone beam computed tomography and its variability in Belgian and Chilean population samples. **Imaging Science in Dentistry**, v. 45, n. 2, p. 95–101, 2015.

TOURÉ, B. et al. Analysis of reasons for extraction of endodontically treated teeth: A prospective study. **Journal of Endodontics**, v. 37, n. 11, p. 1512–1515, 2011.

TU, M. G. et al. Prevalence of Three-rooted Mandibular First Molars among Taiwanese Individuals. **Journal of Endodontics**, v. 33, n. 10, p. 1163–1166, out. 2007.

TU, M. G. et al. Detection of Permanent Three-rooted Mandibular First Molars by Cone-Beam Computed Tomography Imaging in Taiwanese Individuals. **Journal of Endodontics**, v. 35, n. 4, p. 503–507, abr. 2009.

VERA, J. et al. One- versus two-visit endodontic treatment of teeth with apical periodontitis: A histobacteriologic study. **Journal of Endodontics**, v. 38, n. 8, p. 1040–1052, 2012.

VERTUCCI, F. J.; GAINESVILLE, F. Root canal anatomy of the human permanent teeth. **Oral surgery, oral medicine, and oral pathology**, v. 58, n. 5, p. 589–599, 1984.

VIANNA, M. E. et al. In vivo evaluation of microbial reduction after chemo-mechanical preparation of human root canals containing necrotic pulp tissue. **International Endodontic Journal**, v. 39, n. 6, p. 484–492, 2006.

WANG, Y. et al. Evaluation of the root and canal morphology of mandibular first permanent molars in a western chinese population by cone-beam computed tomography. **Journal of Endodontics**, v. 36, n. 11, p. 1786–1789, nov. 2010.

WU, D. M. et al. Accuracy of direct digital radiography in the study of the root canal type. **Dentomaxillofacial Radiology**, v. 35, n. 4, p. 263–265, jul. 2006.

YILMAZ, F. et al. Cone beam computed tomography aided diagnosis and treatment of endodontic cases: Critical analysis. **World Journal of Radiology**, v. 8, n. 7, p. 716, 2016.

ZAATAR, E. I. et al. Frequency of endodontic treatment in Kuwait: Radiographic evaluation of 846 endodontically treated teeth. **Journal of endodontics**, v. 23, n. 7, p. 453–456, 1997.

ZADIK, Y. et al. Analysis of factors related to extraction of endodontically treated teeth. **Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology**, v. 106, n. 5, nov. 2008.

ZHANG, R. et al. Use of cone-beam computed tomography to evaluate root and canal morphology of mandibular molars in Chinese individuals. **International Endodontic Journal**, v. 44, n. 11, p. 990–999, nov. 2011.

ZHANG, X. et al. A cone-beam computed tomographic study on mandibular first molars in a Chinese subpopulation. **PLoS ONE**, v. 10, n. 8, 4 ago. 2015.

ZHENG, Q. HUA et al. Radiographic Investigation of Frequency and Degree of Canal Curvatures in Chinese Mandibular Permanent Incisors. **Journal of Endodontics**, v. 35, n. 2, p. 175–178, fev. 2009.