

REVIEW ARTICLE

Preferred Reporting Items for Epidemiologic Cross-sectional Studies on Root and Root Canal Anatomy Using Cone-beam Computed Tomographic Technology: A Systematized Assessment

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SIGNIFICANCE

A small improvement in the global quality of the prevalence studies on root and root canal anatomy has been observed over the years. However, relevant information is commonly missing such as the participant recruitment, frame, adequate sample size, or sufficient CBCT imaging settings. A scientific-based checklist highlights the most pertinent points to guide researchers throughout the experimental design of these studies.

ABSTRACT

Introduction: The purpose of this study was to perform a quality assessment and provide a scientific-based checklist for prevalence studies on root and root canal anatomy by appraising the methodological quality of *in vivo* studies using cone-beam computed tomographic (CBCT) imaging as the assessment tool. **Methods:** A systematic assessment of the literature was conducted, and 211 studies were selected and submitted to a methodological evaluation. Data were grouped into categories such as journal impact factor, open access availability, language, study origin, journal publisher, sample size, and CBCT settings. Interrater agreement was calculated by applying the Holsti method and Cohen kappa. The Kruskal-Wallis test and Pearson correlation coefficient were undertaken to assess the different variables ($\alpha = 0.05$). **Results:** The included studies ($N = 211$) reported data on 247,616 teeth from 41 countries. The maxillary first molar was the most studied tooth ($n = 69$) and the second mesiobuccal canal the most investigated anatomic feature. The highest scores were associated with high-impact journals ($r = 0.482$, $P < .05$), large sample sizes ($r = 0.374$, $P < .05$), non-open access availability ($P < .05$), and English-based language ($P < .05$), but geographic region and journal publisher also had an impact on quality scores. The identified methodological gaps were used to formulate a scientific-based checklist for this type of study.

Conclusions: Although a small improvement in the global quality of the studies was observed over the years, only less than half of the studies correctly addressed the participant recruitment and frame and had an adequate sample size or provided sufficient CBCT imaging settings. The proposed checklist highlights the most pertinent points to guide researchers throughout the experimental design and the implementation of epidemiological cross-sectional studies of this nature. (*J Endod* 2020; **■**:1–21.)

KEY WORDS

Anatomy; cone-beam computed tomography; morphology; prevalence studies; quality assessment

The widespread use of cone-beam computed tomographic (CBCT) imaging as a reliable diagnostic tool in dentistry made this technology extensively available for clinicians and researchers^{1,2}. The main advantage of CBCT imaging is its nondestructive nature, which allows 3-dimensional visualization of the external and internal anatomy of the teeth and the surrounding structures^{3,4}. It is also a relatively low-cost assessment method that can be successfully used in cross-sectional *in vivo* studies using large

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populations to address the influence of different epidemiologic factors on teeth morphology^{5,6}. Large observational epidemiologic studies can be an essential first-line research format to policy makers and health professionals at local, national, and global levels for setting priorities in research direction and funding⁷ or even by creating new hypotheses for further investigations⁸. In endodontics, the extensive use of CBCT technology in clinical practice has led to a widespread growth in imaging databases, making large volumes of data accessible. As a result, a growing number of publications reporting on root and root canal anatomy of different populations have been published in recent years^{6,9}. Although the number of these prevalence studies has increased significantly, methodological shortcomings related to inadequate sample size, incomplete description of participant recruitment, frame, and CBCT imaging settings have been also detected^{10,11}. These flaws are of concern because the suboptimal quality reporting in these publications avoids reproducibility and is likely to have an adverse impact on the improvement of evidence-based practice in endodontics, which may, in turn, compromise the development of treatment policies¹².

Systematic reviews have been proven to provide the most reliable and unbiased resource for developing evidence-based knowledge and recommendations for future research and clinical practice. They provide up-to-date information for individual clinicians and other stakeholders on evidence-based care on their area of interest¹³. Scientific-based research guidelines and checklists also help editors and reviewers to critically assess the quality of publications to ensure that all essential details are reported. Recent

systematic reviews of cross-sectional studies on root and root canal anatomy using CBCT imaging as an analytical tool have identified a lack of assessment guidelines for this type of study^{10,11} and proposed suggestions to reduce the risk of bias while increasing the reliability as well as the reproducibility of the methodology¹¹.

The aim of the present study was 2-fold: first, to systematically assess the literature and correlate the methodological quality score of the *in vivo* studies published on root and root canal anatomy using CBCT imaging as the imaging assessment tool with the studies' sample size, publication year, journal impact factor (IF), language, open access availability, publisher, geographic origin, CBCT brand, and imaging voxel size and, second, based on the previous appraisal, to provide a scientifically based checklist with the preferred reporting items that should be included in the prevalence studies on root and root canal anatomy.

MATERIALS AND METHODS

Search Strategy and Systematized Assessment of the Literature

The systematized quality assessment of prevalence studies on root and root canal anatomy was accomplished between May 2018 and September 2019 without language restrictions. The systematized methodology used to select and extract data from the final pool of studies was similar to the one used in systematic reviews as reported on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses¹⁴ and the Assessment of Multiple Systematic Reviews assessment tool¹⁵; moreover, the search strategy protocol used in the present study

was similar to the one developed in a previously published review⁹.

The systematized assessment of the literature was conducted on 4 electronic databases (PubMed, ScienceDirect, Lilacs, and Cochrane Collaboration) from January 1990–September 2019 in order to identify *in vivo* prevalence studies on root and root canal anatomy using CBCT imaging as the assessment tool. Table 1 summarizes the terms and filters used on each database.

Initially, the title and abstract of each study were reviewed and labeled as relevant or irrelevant according to predefined inclusion/exclusion criteria (Table 2). Subsequently, the full text of the relevant articles was analyzed and relabeled according to the same criteria. The reference list from the relevant studies as well as the 3 peer-reviewed endodontic journals (*International Endodontic Journal*, *Journal of Endodontics*, and *Australian Endodontic Journal*) and 2 peer-reviewed evidence-based dentistry journals (*Evidence-Based Dentistry* and *Journal of Evidence-Based Dental Practice*) were also hand searched. Additionally, when available, authors from the included studies were contacted via e-mail and asked for additional material from their research group, whether as a format of scientific articles or gray literature, or if they were aware of any ongoing project that could be accessed. Two-hundred eleven studies were selected and submitted to a critical appraisal of their scientific merit.

The scientific merit assessment of the full texts took into consideration the checklist for prevalence studies from the Joanna Briggs Institute (JBI) critical appraisal tool⁷. The JBI checklist of prevalence studies is composed of 9 questions (Table 3) that were labeled as 1 (yes), 2 (no), 3 (unclear), or 4 (not applicable),

TABLE 1 - The Terms Used in Each Electronic Database

Database	Terms used	Filters
PubMed	("cbct"[all fields] OR "cone-beam computed tomography"[all fields] OR "cone beam computed tomography"[all fields] OR "cone beam computed tomography"[MeSH Terms]) AND ("tooth"[all fields] OR "tooth"[MeSH Terms] OR "root canal"[all fields] OR "root canal"[MeSH Terms] OR "anterior"[all fields] OR "premolar"[all fields] OR "premolar"[MeSH Terms] OR "molar"[all fields] OR "molar"[MeSH Terms]) AND ("anatomy"[all fields] OR "anatomy"[MeSH Terms] OR "morphology"[all fields] OR "morphology"[MeSH Terms] OR "configuration"[all fields])	NF
ScienceDirect	"CBCT" AND "tooth" AND "morphology"	Article type: "Research Articles" and "Short Communications"
Lilacs	((Cone Beam Computed Tomography) OR (CBCT)) AND ((tooth) OR (anterior) OR (premolar) OR (molar) AND ((anatomy) OR (morphology)))	NF
Cochrane Collaboration	"Endodontics"	NF

NF, no filter.

TABLE 2 - Inclusion and Exclusion Criteria for Studies to Be Assessed

Code	Inclusion
IA	Morphologic evaluation performed under CBCT assessment
IB	<i>In vivo</i> study only
IC	Study reports on humans only
ID	Study published from January 1990 to September 2019
IE	Sample size (teeth) is given
IF1*	Study reports any type of root canal classification
IF2*	Study reports the number of root canals
IF3*	Study reports the number of roots
IG	Study performs an analysis by tooth groups
IH	Country of origin is given
	Exclusion
EA	Review studies
EB	Case report
EC	Study includes endodontic-treated teeth
ED	Study includes deciduous dentition

*Present at least 1 of the inclusion codes.

but only option 1 (yes) generated a score. For this assessment, items 5 and 9 of the JBI checklist were excluded from the analysis because they were more inquiry oriented. Therefore, a scoring criterion implemented for each article ranged from 0% (no criteria) to 100% (all included criteria), being categorized as presenting high (if "yes" score was equal or lower than 49%), moderate (if "yes" score was between 50% to 69%), or low (if "yes" score was higher than 70%) risk of bias¹⁶. Two evaluators (D.M. and J.M.) independently assessed the eligible studies, and interrater agreement for qualitative items was calculated by applying the Holsti method and the Cohen weighted kappa coefficient (SPSS v.24.0; IBM Corp, Armonk, NY). The kappa results were interpreted as follows: values ≤ 0 indicated no agreement, 0.01–0.20 none to slight agreement, 0.21–0.40 fair agreement, 0.41–0.60 moderate agreement, 0.61–0.80 substantial agreement, and 0.81–0.99 almost perfect agreement¹⁶. In order to evaluate

possible correlations between the JBI score and the assessed variables after the interrater reliability calculations, the discrepancies were resolved through discussion.

Data Extraction and Analysis

Data were extracted from each selected study ($n = 211$) and grouped into categories such as sample size, publication year, journal IF (2019 Clarivate Analytics Journal Citation Report rankings), language, open access availability, publisher, and study geographic origin. After the assumptions of normality and homoscedasticity were verified through the Shapiro-Wilk and Levene tests, the Kruskal-Wallis with post hoc test with Bonferroni correction was used to undertake a comparison among groups, and the results were expressed as the mean and 95% confidence interval. Pearson correlation coefficients (r) were estimated to identify correlations between JBI assessment, study sample size, journal IF, and year of publication.

A P value $<.05$ was considered to be statistically significant. Considering that question 6 of the JBI critical appraisal (Table 3) was associated with the use of CBCT imaging, the answer was automatically affirmative ("yes") to all studies. Data regarding the CBCT scanner brand/model and voxel size were also documented in order to identify the parameter settings used for the scanning procedure in each study.

Preferred Report Items

Based on the information provided by the systematized scientific literature assessment of the full texts and taking into consideration the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement¹⁷, a complementary scientific-based research checklist, which took into consideration the higher levels of evidence, was specifically designed in order to identify the preferred reporting items to be used in epidemiologic studies on root and root canal anatomy using CBCT technology.

RESULTS

Included Studies

A total of 217 studies obtained by electronic database assessment ($n = 166$), manual search ($n = 45$), and authors' contact ($n = 6$, authors' contact return rate of 27.8%) were categorized as relevant and submitted to a full-text appraisal. From this initial analysis, 6 *ex vivo* studies were excluded (inclusion criteria missing: "IB *in vivo* study"), resulting in 211 studies (Fig. 1) representing data from 42 countries (Australia, Belgium, Brazil, Chile, China, Costa Rica, Colombia, Cyprus, Egypt, England, France, Georgia, Germany, Greece, Iceland, India, Iran, Iraq, Israel, Italy, Korea, Kuwait, Malaysia, Mexico, Nepal, The Netherlands, Pakistan, Peru, Poland, Portugal, Russia, Saudi Arabia, Serbia,

TABLE 3 - Interrater Reliability Test Results between Evaluators Regarding Joanna Briggs Institute (JBI) Critical Appraisal Questions for Systematic Reviews of Prevalence Studies

JBI question	Kappa value	Asymptotic standard error	Agreement percentage
1 Was the sample frame appropriate to address the target population?	0.843	0.041	92.1
2 Were study participants recruited in an appropriate way?	0.771	0.049	88.4
3 Was the sample size adequate?	0.855	0.040	92.7
4 Were the study subjects and setting described in detail?	0.673	0.069	89.0
5 Was data analysis conducted with sufficient coverage of the identified sample?	NA	NA	NA
6 Were valid methods used for the identification of the condition?	*	*	100
7 Was the condition measured in a standard, reliable way for all participants?	0.845	0.042	92.7
8 Was there appropriate statistical analysis?	0.829	0.043	91.5
9 Was the response rate adequate, and if not, was the low response rate managed appropriately?	NA	NA	NA

NA, not applicable.

*No statistic was performed because observers' values were constant.

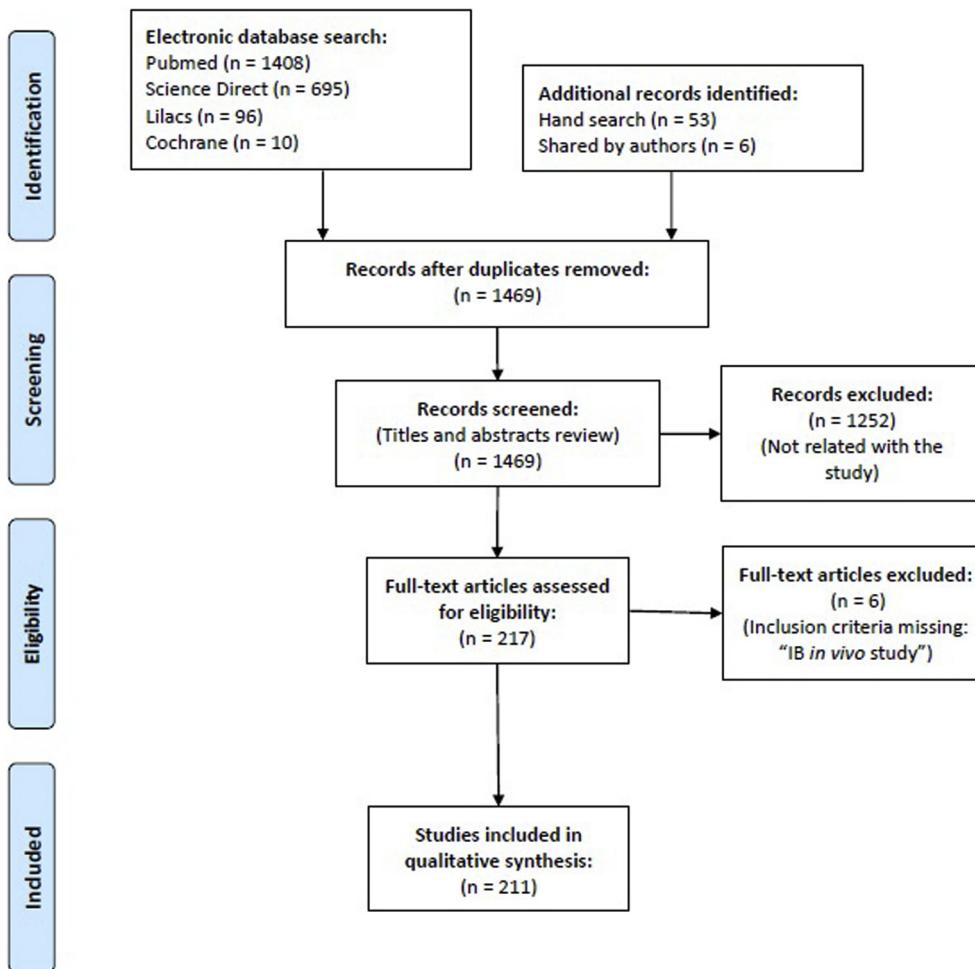


FIGURE 1 – The Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart summarizing the review search strategy.

South Africa, Spain, Syria, Taiwan [China], Thailand, Turkey, the United States, Venezuela, and Vietnam) in 10 different languages (Chinese, English, Hebrew, Italian, Korean, Persian, Portuguese, Russian, Spanish, and Turkish). Two hundred five studies (97.2%) reported data from just 1 country, whereas 6 articles (2.8%) referred to 2 or more countries (Torres et al²², 2015 [n = 2], von Zuben et al⁴⁰, 2017 [n = 9], Martínez et al³⁷, 2018 [n = 2], Martins et al, 2018 [n = 21]⁵, Martins et al, 2018 [n = 2]¹⁹, and Pedemonte et al⁹⁸, 2018 [n = 2]). Figure 2 shows the worldwide distribution of the CBCT studies on root and root canal anatomy according to the country of origin.

Interrater Agreement, Overall Quality Scores, and Risk of Bias

The overall kappa coefficient for JBI assessment was 0.84 (asymptotic standard error of 0.02) corresponding to an almost perfect agreement¹⁶, whereas the overall agreement percentage between observers was 92.2%. Substantial agreement (>80%) was observed for the individual items with

kappa parameters ranging between substantial to almost perfect agreement (Table 3). After this initial appraisal, disagreements between evaluators were discussed, and the final scientific assessment¹⁶ was scored as high (36.97% of the studies), moderate (18.48%), and low (44.55%) risk of bias, with a mean overall score of $60.46\% \pm 0.27\%$. Based on the individual analysis of the JBI checklist⁷, the lowest individual scores were obtained for sample size selection and recruitment (questions 1, 2, and 3) (Fig. 3).

Study Contents

The selected studies ($N = 211$) reported data on root and root canal morphology of 247,616 teeth (average of 1179.12 teeth/study) from at least 79,695 patients (average of 400.48 patients/study). The sample size ranged from 32¹⁸ to 15,655 teeth¹⁹ (excluding data from 10 studies yielding repeated samples) and from 33²⁰ to 3935⁵ patients (excluding 12 studies that did not report the number of patients). The mean teeth sample size of the studies with JBI

scores under and above 50% was 674.12 ± 974.30 ($n = 78$) and 1818.01 ± 2577.62 ($n = 133$), respectively. A positive correlation was found between the study quality scores and teeth sample size ($r = 0.374$, $P < .05$) as well as between journal IF and teeth sample size ($r = 0.236$, $P < .05$).

The anatomy of the root and root canal was assessed simultaneously in 69.67% of the articles ($n = 147$), whereas a single approach to root or canal anatomy was performed in 5.69% ($n = 12$) and 24.17% ($n = 51$) of the studies, respectively. Configuration of the root canal was reported using the Vertucci^{21–23} ($n = 113$, 53.55%) or Weine^{24,25} ($n = 4$, 1.90%) systems. The configuration of C-shaped canal morphology in mandibular molars was assessed according to Fan et al^{22,26,27} ($n = 20$) and Melton et al^{28,29} ($n = 4$), whereas external root configuration was categorized in only a few studies ($n = 9$, 4.27%) using the classification proposed by Zhang et al^{30,31}. In 77 studies (36.49%), analysis of the anatomy was performed without any specific classification system, and

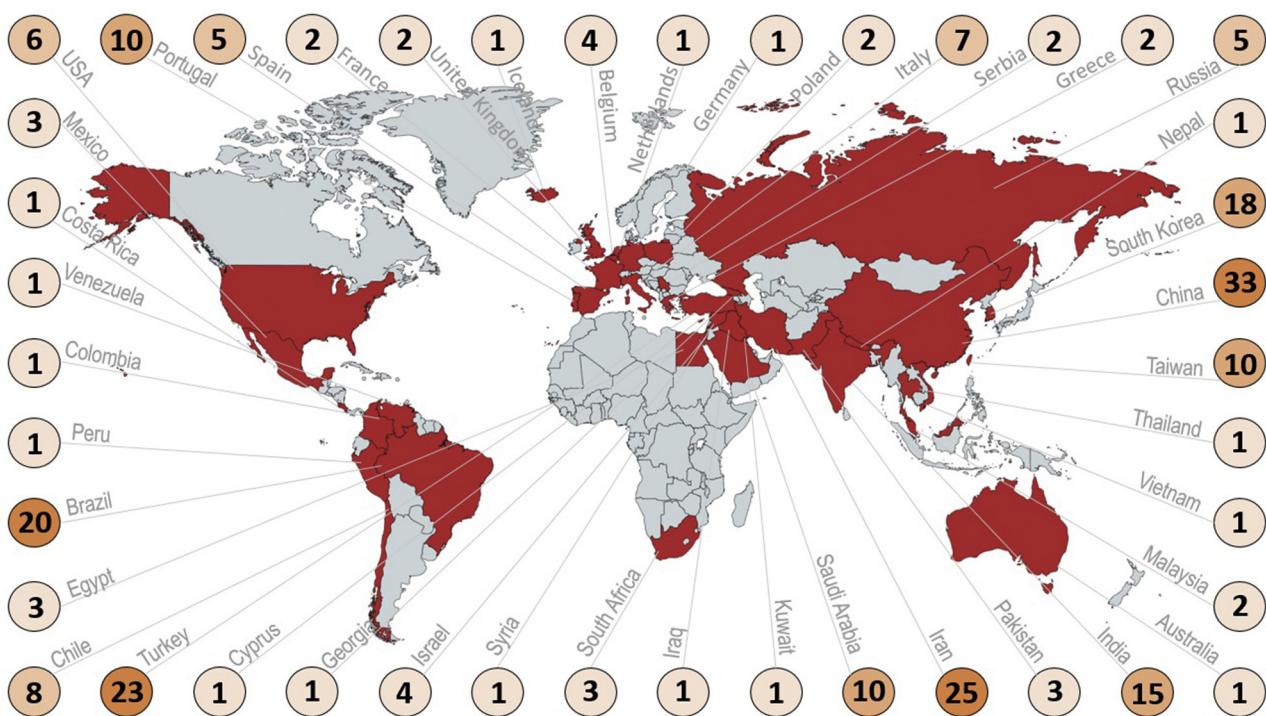


FIGURE 2 – A schematic drawing showing the worldwide distribution of the 211 selected studies on root and root canal anatomy using CBCT imaging as an analytical tool.

the methodology was focused on the presence/absence of a particular anatomic feature, such as the second mesiobuccal canal of maxillary molars (MB2), or simply in the number of roots and/or root canals. The maxillary first molar was the most studied tooth ($n = 69$, 32.70% of all studies), whereas the main anatomic feature investigated was the MB2 canal. Third molars and dens invaginatus were assessed in only 4^{32–35} and 2^{20,36} studies, respectively.

Variable Outcomes

Figure 4A summarizes the proportion of published articles according to journal ranking, whereas Figure 4B shows the total number of

published articles and quality score results over the years. Considering the IF score from the Clarivate Analytics Journal Citation Report, high IF journals ($IF \geq 2.00$) presented an average quality score of $78.71\% \pm 24.36\%$, which was significantly higher than nonindexed journals to PubMed ($41.16\% \pm 22.93\%$) and small IF journals ($IF = 0.0–0.49$, $55.72\% \pm 22.32\%$, $P < .05$; Fig. 4C). The evaluation of mean quality scores according to journal IF showed that high IF journals improved their scores at a higher ratio than the global sample over the years (Fig. 4D).

A positive correlation with a significant difference was found between the JBI scores and journal IF ($r = 0.438$, $P < .05$). A positive

correlation was also noted between the publication year and quality scores in all of the journal rankings (outside PubMed: $r = 0.220$, $P > .05$; IF 0.0–0.49: $r = 0.070$, $P > .05$; IF 0.50–1.99: $r = 0.215$, $P > .05$; and IF ≥ 2.00 : $r = 0.482$, $P < .05$).

Statistically significant JBI higher scores were observed in prevalence studies published in non-open access journals ($n = 82$) and the English language ($n = 190$) compared with open access articles ($n = 127$) or articles published in other languages ($n = 21$, $P < .05$) (Fig. 5A). Regarding the geographic origin of the studies, 70.62% of the articles ($n = 149$) were from Western and Eastern Asia (Table 4), with the latter having a significantly higher JBI score (68.20) than the former (53.86, $P < .05$) (Fig. 5B). Score differences were also observed among journal publishers (Fig. 5C).

CBCT Scanner Brands and Voxel Size

Information provided in the pooled articles regarding the CBCT brand (and/or manufacturer) and imaging voxel sizes was limited. Nine studies (4.27%) did not mention the scanner brand, and 50 articles (23.7%) did not mention the voxel size. In the 202 studied articles (95.7%) that specified the CBCT brand, a single unit was used in 194 studies, whereas the others used multiple devices in a total of 243 scanners. The most used brands were from Newtom (QRsrl, Verona, Italy;

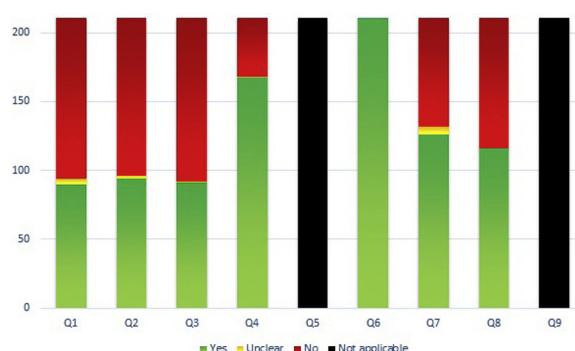


FIGURE 3 – The final quality assessment scores for the JBI critical appraisal checklist for prevalence studies after consensus between evaluators.

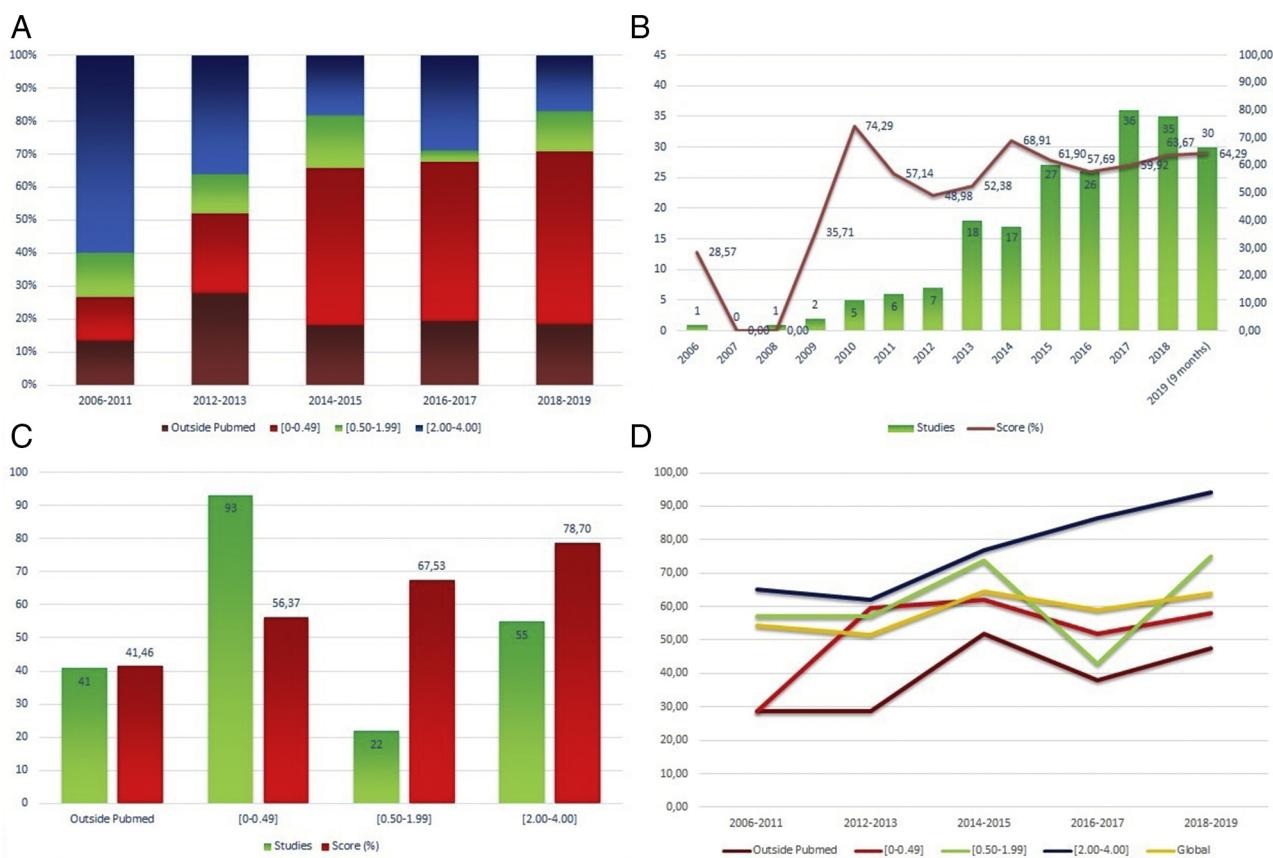


FIGURE 4 – The relation among the JBI critical appraisal score, publication year, and journal IF. (A) The proportion of prevalence studies published over the years according to the journal IF. (B) The global JBI score and the number of published articles over the years. (C) The JBI score according to the journal IF. (D) The JBI score over the years according to the journal IF.

$n = 46$), Promax (Planmeca, Helsinki, Finland; $n = 38$), I-Cat (Imaging Sciences International, Hatfield, PA; $n = 30$), Carestream (Carestream Health, Rochester, NY; $n = 28$), Accuitomo (Morita, Kyoto, Japan; $n = 21$), and Galileos (Sirona Dental Systems GmbH, Bensheim, Germany; $n = 15$) series. The imaging voxel size in the selected studies varied from 70–100 μm ($n = 32$, 14.3%), 101–150 μm ($n = 57$, 25.5%), 151–200 μm ($n = 79$, 35.4%), and above 200 μm ($n = 55$, 24.6%)³⁹ up to 600 μm . A unique voxel size was used in 139 of 161 articles that stated this parameter, whereas in the other 22 studies multiple voxel sizes were used.

Preferred Report Items

More than half of the studies ($n = 121$, 57.34%) lacked presenting data regarding the representativeness of the sample in the populations intended to be addressed, the way the CBCT examinations were selected and included in the studies, or the way participants were recruited (Fig. 3). In 120 articles (56.87%), sample size calculation was

not properly performed (Fig. 3), whereas information regarding CBCT scanner brands and scanning setup were also commonly missing. Data regarding patients' demographics (sex, age, and ethnic groups), CBCT examination field of view, observer reliability, or appropriate statistical analysis were not properly addressed in these studies. Keeping in mind the systematized evaluation of the methodology of the previous studies, a study design checklist that takes into consideration the best available levels of evidence and the specificities of root and root canal morphology assessment is now proposed (Table 5).

DISCUSSION

Critical appraisal of the methodological quality of primary studies is an essential feature of systematic reviews and has been an ongoing exercise in evidence-based dentistry^{15,16,227–229}. It has been demonstrated that the lack of adherence to a priori-defined validity criteria would explain why primary studies on the same topic provide

different results^{227,229}. Thus, systematized assessment of evidence is currently well accepted as the ideal method to summarize the literature relating a health care topic⁷. Several study design guidelines have been proposed in order to create standardized rubrics that are supposed to evaluate the methodological quality and risk of bias according to the study format and design^{14,17,230}. One of the appraisal tools available for prevalence studies is the JBI checklist used in this study. Although the JBI checklist for prevalence studies addresses critical issues of internal and external validity that must be considered when assessing the validity of prevalence data⁷, it also presents the limitation of being too generalized and not focusing on certain key points that are of relevant importance when assessing tooth morphology through a CBCT examination. Even still, the results of this appraisal can be used to further synthesize and interpret the study outcome to ensure that the test condition was measured reliably and objectively⁷. In endodontics, despite the increasing number of *in vivo* prevalence studies

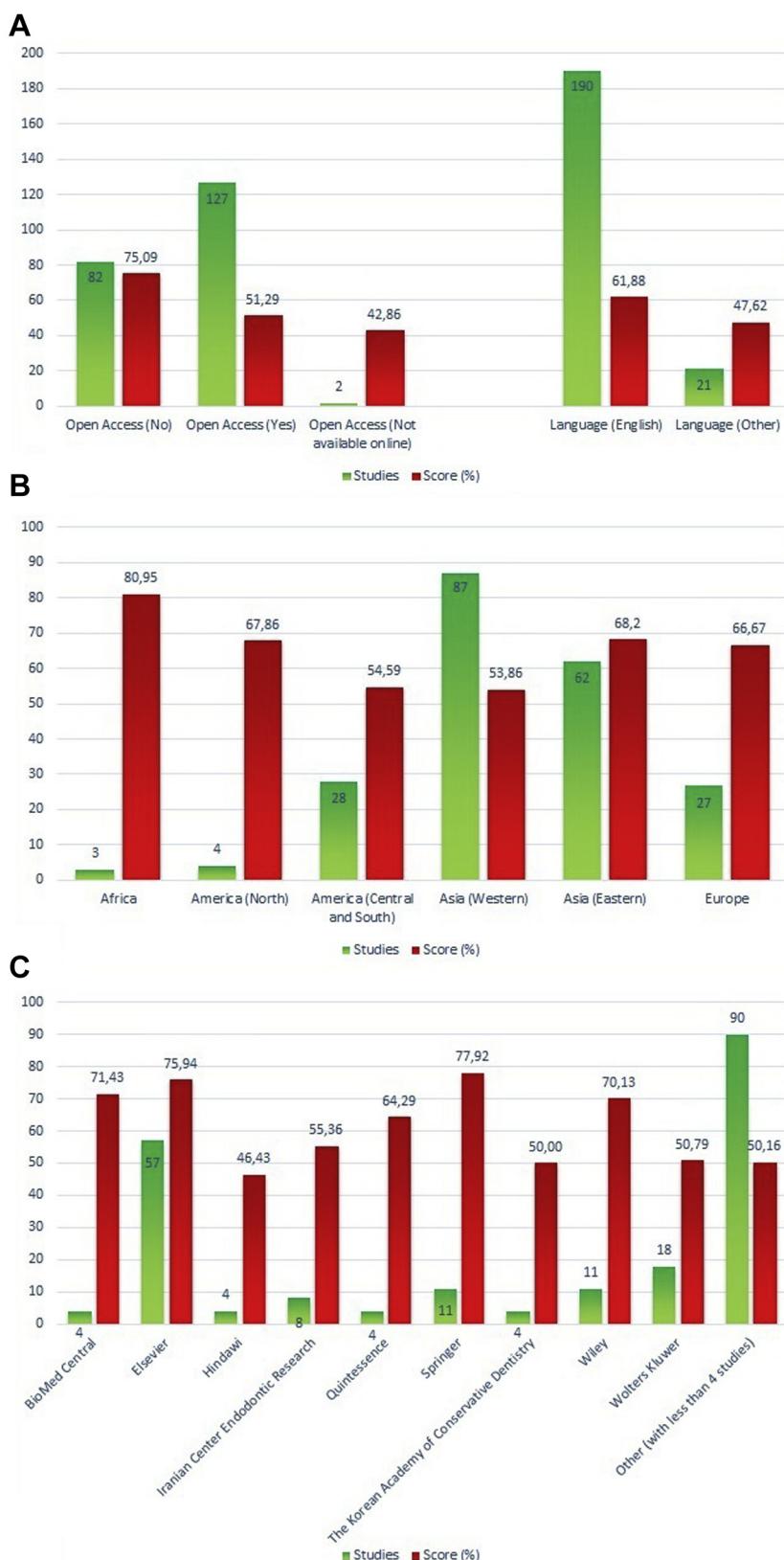


FIGURE 5 – The influence of (A) open access availability and manuscript language, (B) study origin, and (C) journal publisher on the JBI critical appraisal score.

on root and root canal morphology since the introduction of CBCT technology, no quality assessment of these studies using previously validated appraisal tools was performed thus far. The present study aimed to assess the available literature and methodology used in these studies in order to identify possible limitations and bias that could interfere with the analysis and interpretation of the results. This has aid in identifying the existing gap in the literature, creating a system that ascertains the quality of the evidence produced and helped to develop a scientific-based checklist to support future similar studies.^{10,11}

Although 1 of the major advantages of the prevalence studies is the possibility of assessing a large amount of data, 1 of the poorly addressed aspects of the analyzed studies was the inappropriate sample size. Only 44.08% of the studies ($n = 91$) had a valid sample size for the described objectives according to the JBI assessment methodology, which provides a formula to determine if the sample size is correct or insufficient. Briefly, this formula is based on recommendations proposed by Daniel²³¹ and Naing et al²³² and is presented as $n = Z^2P(1 - P)/d^2$, where Z counts for the Z statistic for a level of confidence (eg, Z values would be 1.96 and 2.58 if the level of confidence is 95% or 99%, respectively), P represents the expected prevalence or proportion (if prevalence equals 20%, P counts as 0.2), and d is precision (in a proportion of 1, if set at 5%, then $d = 0.05$). In the prevalence cross-sectional studies appraised in this systematized literature review, the original sample size tended to be subdivided into small subgroups for comparison, which ultimately led to sample sizes that are too small to perform a proper analysis. This subdivision was 1 of the main reasons why the studies did not reach the optimal sample size and lost statistical power for comparison. Researchers should be aware of this phenomenon and perform a previous sample size calculation in order to provide an appropriate number of samples in each subgroup intended to be compared or to present the data in an observational manner, avoiding the inappropriate analytical analysis of subgroups with small sample sizes. Other limitations of the included studies were the lack of a proper description of the recruitment process for the participants (properly addressed in 44.55% of the studies) or the sample frame of the target population (correctly addressed in 42.65% of the studies). A large number of studies did not mention the origin (place where the data were collected, $n = 32$, 15.17%), patients' nationality ($n = 36$, 17.06%), or their ethnic group ($n = 158$, 74.88%). It is important to understand that unless all the individuals of the

TABLE 4 - Studies Pooled in the Present Assessment

Origin	Countries	References
Africa	Egypt	5,37,38
	South Africa	5,39,40
East Asia	China	4,5,19,21,40–68
	Malaysia	69,70
	Nepal	71
	South Korea	24,28,29,32,72–85
	Taiwan	30,86–94
	Thailand	95
Europe	Vietnam	96
	Belgium	5,22,97,98
	England	5,40
	France	5,99
	Germany	100
	Greece	5,25
	Iceland	5
	Italy	5,101–106
	Poland	20,107
	Portugal	5,19,40,108–114
	Serbia	115,116
	Spain	5,40,117–119
	The Netherlands	5
North America	Mexico	5,33,40
	USA	5,40,120–123
Central America	Costa Rica	5
South America	Brazil	5,26,40,124–140
	Chile	18,22,97,98,141–144
	Colombia	145
	Peru	146
Oceania	Venezuela	5
West Asia	Australia	5
	Cyprus	147
	Georgia	148
	India	5,31,34,35,40,149–158
	Iraq	159
	Iran	160–184
	Israel	23,185–187
	Kuwait	5
	Pakistan	188–190
	Russia	27,191–194
	Saudi Arabia	195–204
	Syria	5
	Turkey	36,205–226

population under study have been assessed, as done in a nationwide census, the groups under analysis are just a part of that population, being technically defined as a subpopulation. The omission of the sample frame and recruitment process makes it difficult to realize if the subpopulation under study properly addresses the target population. Moreover, knowing the sampling methods (probabilistic sampling such as random or clusters or nonprobabilistic sampling such as convenience sampling) or the recruitment method (such as consecutive or all available) is important information to exclude sampling bias.

Tooth morphologic variations among populations have been previously documented, and those differences might be as old as the *Homo sapiens* itself^{233–237}. Xing et al²³³,

comparing the crown anatomy of mandibular premolars between European and Asian (Zhoukoudian) primitive humans from the Pleistocene Epoch, noted that some occlusal surface landmarks had disparities between specimen groups expressed in a stronger way than the corresponding similarities. Although the major ethnic traits have been documented in the crown, possibly because of the adaptation to environmental factors²³⁴ during the human world colonization, differences have been also documented on root morphology in anthropological studies (eg, variations in the number of roots of mandibular canine between Basque population and European standards²³⁵, maxillary second molars between Africans and Asians²³⁶, or the presence of the Tome root among different populations²³⁷). More recently,

Silva et al¹³⁸ recommended that ethnicity should be taken into consideration during clinical procedures in endodontics because of the prevalence of specific anatomic variations in each population. However, despite the fact that many articles have suggested the ethnicity influence on root and root canal anatomy in several groups of teeth^{88,107,119,132,166,171,177,190,211}, in fact, there is a huge gap in knowledge in the literature. From the 53 studies that provided ethnical description of the subpopulations under analysis, only 23 presented legit ethnic groups such as Caucasians or whites ($n = 11$), Mongoloid ($n = 5$), Han ($n = 2$), Malay ($n = 2$), Arab ($n = 1$), Asian ($n = 1$), and mixed "Caucasian and Asian" ($n = 1$). In the other studies, the terminologies used might be understood as an attempt to present an ethnicity such as mixed Europeans; Africans, Asians, and Native Americans ($n = 3$); native Chinese ($n = 2$), mixed (African-American, Asian, Caucasian, and Hispanic; $n = 2$), Chinese descendants ($n = 1$), ethnic Indian ($n = 1$), ethnic Korean ($n = 1$), ethnic Russian ($n = 1$), native Taiwanese ($n = 1$), Turkish Cypriot ($n = 1$), or purely ethnic East Anatolian Turkish ($n = 1$). In addition, expressions that represent both nationality and ethnicity have been also used, which include Korean ($n = 11$), Egyptian ($n = 2$), Serbian ($n = 2$), and Thai ($n = 1$), whereas it is not clear if the authors were referring to the patient's nationality or ethnicity. These legit ($n = 23$, 10.90%), similar ($n = 14$, 6.64%), and joint terminologies (nationality/ethnicity) ($n = 16$, 7.58%) all together represent only 25.12% of the pooled studies. The vast majority of the articles rely on nationality ($n = 175$, 82.94%) to describe the subpopulations. It is also important to understand that some nations are markedly multiethnic such as Brazil, Australia, the United States, and England (particularly the capital London). Traditionally, the analyzed subpopulation represents the patients who attended the clinical practices from where the data were collected⁴⁰ and not necessarily a specific ethnic group. Therefore, in these cases, the association of the countries with specific ethnic groups is erroneous. Moreover, even in countries considered not so much pluriethnic, several inside-nation ethnicities might be present depending on the regions of the country being assessed such as India, Iran, or China. Regarding China, 1 study reported that the assessed subpopulation was composed by 44 minor ethnic groups plus the major Han group⁶¹. However, all of them could be considered as Asians (1 of the 3 main ethnic branches together with whites and Africans). It is important to notice that some studies clearly stated as a methodological limitation that the evaluated ethnic groups were not precisely identify^{40,52,177}.

TABLE 5 - Specific Preferred Reporting Items for Cross-sectional Studies on Root and Root Canal Anatomy Using Cone-beam Computed Tomographic (CBCT) Technology That Were Defined Keeping in Mind the Systematized Methodological Assessment and Strengthening the Reporting of Observational Studies in Epidemiology Statement

Main topics	Specific recommendations
Title	The type of study should be mentioned (such as “cross-sectional study” or “prevalence study”) and “cone-beam computed tomography” should appear in the title.
Key words	It should include “cross-sectional study” and “cone-beam computed tomography.”
Aim	The purpose of the study must be clearly stated at the end of the Introduction section including, if possible, a study question, null hypothesis, or “Condition, Context, Population” (Co-Co-Pop) format.
Methodology	
Participants (<i>in vivo</i> assessment)	Present the population of interest, its geographic region and demographic data such as mean age and range, and sex proportions. Describe the recruitment and sampling method such as probability sampling (simple random, stratified random, systematic random, or cluster random sampling) or nonprobability sampling (quota, convenience or purposive sampling). Sample size determination should also be clearly stated and adequate to the measure of interest.
CBCT	State where (university, private practice, public clinic, etc), why (was the scan performed or not because of the study?), and when (date interval in which images were acquired) the CBCT examinations were performed. Mention the inclusion/exclusion criteria for the CBCT examinations before the selection process. Mention the brand and manufacturer of the CBCT scanner and describe scanning settings such as voxel size ($\leq 200 \mu\text{m}$, preferably) and field of view (small and focused, preferably). State the name, brand, and manufacturer of the visualization software used for the assessment of the data set.
Morphology concept and assessed teeth (variables)	State tooth eligibility. List which teeth groups and morphologies were assessed (root, canal, or both), and which classification system was used (Vertucci, Weine, Fan, Melton, etc). Describe in detail if a classification was purposely elaborated (or adapted) for the study. State primary outcomes.
Assessment	Present the assessment methodology and data extraction, including step-by-step screening procedures, planes that were used in the analysis (axial, sagittal, and/or coronal) and period of time in which it was done.
Observers	State if the observers were educated and trained to perform the assessment of the primary outcomes, catalog anatomy, and use CBCT imaging as an assessment tool. Calibration protocol and inter- and intrarater assessment reliability must be performed.
Potential sources of bias	Present the potential sources of bias or confounding factors. Report the reasons and percentages of patient/specimen exclusion, including imaging reasons such as CBCT artifacts.
Final sample size	Explain how the final sample size was reached for observational studies or how the final sample size was estimated for analytical studies.
Reliability	In case of only 1 observer, intrarater reliability test must be reported. If more than 1 evaluator were used, state if the appraisal was performed in the same way for all observers and the results of intra- and interrater reliability tests.
Statistical analysis	For observational studies, state how specific variables were grouped and measured. For analytical studies, it must be clearly state the power and significance of the statistical test used.
Ethics committee	Mention if the study has been approved by an ethics committee according to the journal guidelines.
Results	
Primary outcomes	Present the results for primary outcomes with mean percentages and confidence intervals.
Other analysis	If relevant, report subgroup comparisons or association measurements (such as odds ratio).
Visual documentation support	Attest to the study output quality by showing representative images of the observed morphologies.
Discussion	
Outcomes interpretation	Summarize the main results and fit them to the overall outcome. Compare the results with studies using similar methodology or from the same geographic region. If relevant, compare the results with other studies that used reliable assessment methodologies or have other significant information on the topic.
Strength and limitations	Report on the strengths and limitations of the study design.
Generalizability	Debate the external validity of the outcomes.
Future research	State implications or recommendations for future research.

In the current assessment, limited information regarding CBCT settings was also observed despite the fact that it was the analytical tool used to evaluate the anatomy of roots and root canals in all of the selected studies. For instance, scanner brand and voxel size resolution were not reported in 4.27% ($n = 9$) and 23.70% ($n = 50$) of the studies, respectively, whereas in 54 studies (25.59%) the CBCT voxel size used was above 200 μm ,

which represents more than half of the appraised studies (53.55%, 113/211 studies). It is important to point out that the optimal voxel size to support the reliability of the method for the study of root canal anatomy is task specific. According to some authors, external root morphology can be accurately evaluated using 300- μm CBCT voxel size^{238,239}, but for the internal anatomy of teeth, a 200- μm voxel size was considered

more appropriate²⁴⁰. These recommendations are supported by 2 recent meta-analyses that confirmed voxel sizes lower than 200 μm as not being a source of heterogeneity in the outcome of CBCT studies on root canal anatomy^{11,241}. Therefore, to perform the epidemiologic assessment of root and root canal morphology using a CBCT system, a maximum voxel size of 200 μm is recommended. In this literature assessment, it

was also observed that the majority of the pooled studies analyzed both root and root canal morphology, but only half of them (53.55%, $n = 113$) used the same classification system (Vertucci classification)²⁴² to describe root canal configuration, whereas approximately one third (36.49%, $n = 77$) did not use any specific notation, avoiding a proper comparison among them. Several groups of teeth or specific anatomic features were not properly explored considering that most studies focused on the anatomy of the maxillary first molar (32.70%, $n = 69$) with special interest for MB2 (33.65%, $n = 71$) or C-shaped canal morphology in mandibular second molar teeth (11.37%, $n = 24$).

With the development of new concepts, methodologies, and study designs, an improvement in the quality and reliability of the study results would be expected over time¹⁶. This aspect was observed in the present study because the JBI score increased 29.25 percentage points from 2006–2011 to 2018–2019 for journals with an IF higher than 2.0 (Fig. 4D). However, the global mean scores for JBI improved only 9.67 percentage points. This small overall improvement might reflect the slow improvement observed in journals with the lowest IF, which lately published studies with low-quality designs (scores around 50%) (Fig. 4D). On the other hand, the JBI mean score of journals with the highest IF was 94.29% (2018–2019 period), with 14 of 22 publications scoring 100% between 2017 and 2019. It is noteworthy that these results are in accordance with the quality assessments applied to other study designs^{16,243}. Between 2006 and 2011, 60% of the prevalence studies were published in high IF journals ($IF \geq 2.00$), whereas the nonindexed to PubMed (outside PubMed) or small IF journals ($IF 0.0–0.49$) represented only 26.67% of the publications. However, in the 2018/2019 period, this tendency was reversed with nonindexed and small IF journals publishing 70.77% of the studies (Fig. 4A), whereas only 16.92% of the studies were available in high IF journals. Although the ratio of publications between high- and small-

impact IF journals has been changed, the number of publications has grown in all types of journals, with an average of 7 new studies on root and canal anatomy using CBCT technology every month in 2019 (from January to September) (Fig. 4B). With the increasing number of publications on this topic and the small availability of high IF journals in endodontics, it is possible that authors have changed their submissions to journals with the lowest impact factors in order to enable publication, which may explain the overall low improvement on the quality assessment scores.

Taking into account the previously discussed methodological gaps identified in this systematic literature assessment as well as the STROBE statement¹⁷, a complementary scientific-based checklist containing the preferred reporting items that should be addressed in cross-sectional studies on root and root canal anatomy using CBCT technology is proposed (Table 5). Not replacing the ideologies of the observational study designs already documented, the new checklist presents the advantage of being highly specific for observational cross-sectional studies on root and root canal morphology using CBCT imaging, which allows a more reliable cross-sectional study design on tooth anatomy as opposed to STROBE and JBI, which are more transversal and allow for the assessment of other outcomes that might not even be related to anatomy. Although presenting the disadvantage of being less adjustable to other matters of interest or other observational study designs, the proposed checklist allows the replacement of the CBCT-related information and item for other diagnostic tools, allowing an adaptation for other evaluation methods. The items that compose the checklist intend to guide authors and reviewers in the publication process and include recruitment, sampling method, scanner description, morphology assessment, evaluation of bias, sample size, reliability, outcomes, strengths/limitations, and other relevant points. It is recommended that authors from future studies on root and root

canal anatomy using CBCT imaging should make an effort to select an adequate sample size; avoid the use of an excessive division of the sample into subgroups; and preserve 1 of the major advantages of these type of epidemiologic studies, which is the possibility of evaluating large subpopulations. Detailed descriptions of participant recruitment and frame are also necessary as well as the CBCT imaging settings. In summary, researchers must consider using study design checklists for quality assessment such as the JBI assessment tool⁷ or the scientific-based checklist provided in this study (Table 5) when designing and conducting a prevalence study on root canal anatomy using a CBCT system in order to increase the validity and strength of the findings and also the reproducibility of the method.

CONCLUSIONS

Despite a small improvement in the global quality of *in vivo* prevalence studies using CBCT imaging on root and root canal morphology over the years, only less than half of the studies (40%) correctly addressed the participant recruitment, frame, and CBCT imaging settings or had adequate sample size. Other relevant variables that had a significant influence on the overall quality of the studies include open access availability, language, study sample size, geographic region of origin, and journal publisher. The proposed checklist highlights the most relevant points to guide researchers throughout the experimental design of this type of epidemiologic cross-sectional study. This will aid in increasing the validity/strength of the findings as well as improve the methodological reproducibility and data comparability among different populations.

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