ORIGINAL RESEARCH PAPER
Volume - 10 | Issue - 12 | December - 2021 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr
INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

METHODS TO STUDY ROOT CANAL ANATOMY: A SYSTEMATIC REVIEW

Endodontics

Shishir Singh* Department of Conservative Dentistry and Endodontics, Terna Dental College and Hospital, Navi Mumbai. *Corresponding Author

Naren Ramachandran Department of Conservative Dentistry and Endodontics, Terna Dental College and Hospital, Navi Mumbai.

Rajesh Podar Department of Conservative Dentistry and Endodontics, Terna Dental College and Hospital, Navi Mumbai.

Romi Jain Department of Public Health Dentistry, Terna Dental College and Hospital, Navi Mumbai.

Nikhil Bhanushali Department of Public Health Dentistry, Terna Dental College and Hospital, Navi Mumbai.

Gaurav Kulkarni Department of Conservative Dentistry and Endodontics, Terna Dental College and Hospital, Navi Mumbai.

Padmini Chandrasekhar Department of Conservative Dentistry and Endodontics, Terna Dental College and Hospital, Navi Mumbai.

ABSTRACT

Introduction: A variety of methods has been used to study the root canal anatomy. Before radiography became firmly established in dental practice, techniques such as injection-moulded models, diaphanization, and sectioning were used to study the internal anatomy of teeth. Two-dimensional radiography was a convenient method to study the root canal anatomy, but it provided limited information due to distortion, superimposition, and lack of 3-dimensional information. Cone beam computed tomography, and more recently micro-CT have been used in most of the recent studies on root canal anatomy as they are non-invasive and provide multiplanar data. Each of these methods has its own merits and knowing when to choose which method whilst planning a study is important.

Methods: The systematic review was registered in PROSPERO. Three electronic databases were accessed, and a hand search was performed in peer-reviewed journals in endodontics. Studies that met the pre-defined inclusion and exclusion criteria were selected or rejected, respectively. The screened articles were subjected to Risk of Bias (ROB) assessment for evaluation of their scientific merit.

Results: The selected studies included data from at least 288478 teeth studied, of which, 206270 teeth were studied by CBCT, 30980 teeth were studied by clearing technique, 3616 teeth were studied by sectioning, 9027 teeth were studied by Micro CT, and 1191 teeth were studied by resin or plastic infiltration. The commonest parameters studied were canal morphology, presence as well as morphology of MB2 canals in maxillary molars, C-shaped canal morphology in mandibular molars, presence of extra roots and canals, isthmuses, and racial characterisation of the study population.

Conclusion: With the advent of 3-dimensional radiographic techniques such as CBCT and micro-CT, these methods have become the mainstay of root canal anatomy studies, especially as these techniques have become less expensive and more widely available. Certain techniques such as clearing are relevant even today as they provide excellent details on the intricacies of the canal system. Depending on the study characteristic to be studied, the appropriate method must be employed.

KEYWORDS

INTRODUCTION

Canal instrumentation is one of the most important phases of root canal treatment (1). Endodontic infection is biofilm-based and chemo-mechanical debridement aims to physically disrupt the biofilm present in the main canal walls as well as its numerous branches and complexities. It is known that even with conventional root canal treatment procedures, bacterial biofilms are found within the main canal as well as the isthmus (2, 3). Complex root canal anatomy is a non-modifiable challenge to the elimination of the biofilm and smear layer for a successful outcome. Although on the radiograph, root canals appear as straight white lines, in reality they are a network of fine, irregular channels with numerous extensions, isthmuses, and anastomoses. Fisher, having observed this complex interconnecting system with interspersed islands of dentine, rightly coined the expression "root canal system" rather than "root canal" (4).

Knowledge of anatomy is a prerequisite in any surgical procedure. So too it is for root canal treatment where a thorough knowledge of the root canal system morphology along with its variations is required for improving the treatment outcome. This includes information about the expected number of canals in a particular tooth, the location of their orifices, and their course from the orifice to the apical foramen. A multitude of studies has been performed in the past using a variety of techniques to study the root canal anatomy. These techniques include diaphanization or clearing, plastic or resin models, sectioning, and radiographic methods such as conventional radiography, and more recently cone beam computed tomography and micro-CT. Numerous classification systems exist, and they all generally classify the canal system based on the pattern of division of the main canal as traced from the canal orifice to the apical foramen. Okumura gave the first classification for root canal anatomy(5). Weine *et al*. were the first to study the canal anatomy using sectioning and radiographic methods(6). Vertucci used the clearing technique and added further categories of canal anatomies (7).

Gulabivala *et al*. and Ng *et al*. added additional modifications which could not be classified using the Vertucci classification (8-10). Additional modifications were added by Sert and Bayirili (11). An additional 37 types were added based on micro-CT studies by Versiani and Ordinola-Zapata(12). Ahmed *et al*. provided a new system of classifying root and root canal morphology that was created with the aim of being more "simple, practical and accurate"(13).

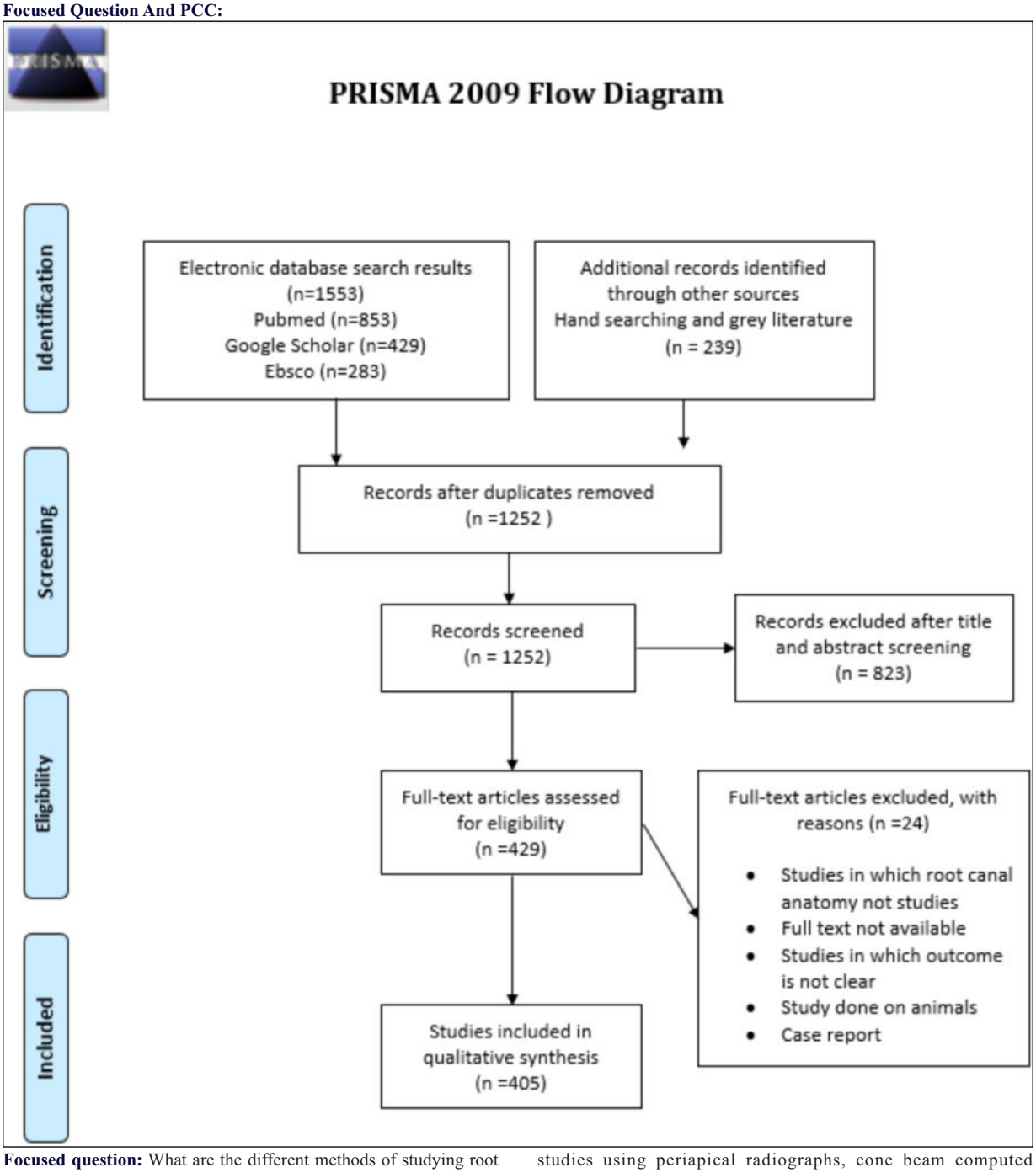
The variation in root canal anatomy depends on the type of tooth, as well as the racial and ethnic constitution of the study population. The observed trend in canal anatomy studies is that earlier studies tended to use complicated and invasive methods such as clearing and sectioning whereas, recent studies have used simpler and non-invasive radiographic techniques such as micro-CT.

While the literature on the canal anatomies itself has been reviewed in much detail, the same is not true for the methods used to study the canal anatomy. Knowledge of the various methods used to study root canal anatomy has importance in education as well as endodontic treatment. Hence the aim of this systematic review was to analyse the various techniques used for studying the canal anatomy.

MATERIALS AND METHODS

This systematic review followed Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) recommendations (http://www.prisma-statement.org) and was registered on the PROSPERO database under number CRD42020165275.

Focused Question And PCC:



Focused question: What are the different methods of studying root canal anatomy?

PCC:

Population: Human permanent teeth

Condition: Root canal anatomy of human permanent teeth

Context: Various methods used to study the root canal anatomy

Eligibility Criteria:

Inclusion Criteria:

1. All in-vitro, ex-vivo, and clinical studies reporting information about root canal anatomy of human permanent teeth.
2. Articles which reported on the number of roots, their morphology, and canal configuration with the use of dyes, decalcification, dehydration, clearing technique, sectioning, clinical techniques, studies using periapical radiographs, cone beam computed tomography (CBCT), micro-CT, spiral-CT or any other technique.
3. Articles in the English language or where English translation was possible
4. Articles published from the year 1925 till December 31, 2020.

Exclusion Criteria:

1. Studies assessing pathologies such as resorption or other periapical pathologies
2. Studies of root canal anatomy in primary teeth
3. Interventional studies, editorials or non-primary research
4. Studies providing insufficient information to investigate the question of interest.

Information sources and search strategy:

The concept table included the key concepts, controlled vocabulary terms as well as free text terms. The controlled vocabulary terms

(MeSH Terms) were obtained by searching the key concepts in the MeSH database.The free text terms were obtained after a thorough evaluation of related articles, thesaurus and dictionaries as well as entry terms and subheadings of the relevant MeSH terms.

The search was independently performed by three examiners (insert SS, RJ, & NB) in the following databases initially: MEDLINE through PubMed, EBSCOhost, and Google Scholar. An additional hand search was performed in the following journals: International Endodontic Journal, Journal of Endodontics, European Endodontic journal. Cross referencing and hand search was also performed to find any relevant article.

The specific search strategy used was as follows: *(((((root canal anatomy) OR (root canal morphology)) OR (root canal configuration)) OR (root canal system)) AND ((((((((((((((((((((cone beam computed tomography) OR (cbct)) OR (clearing technique)) OR (canal staining)) OR (canal staining and tooth clearing technique)) OR (digital radiography)) OR (cross sectioning)) OR (modelling technique)) OR (radiological techniques)) OR (decalcification)) OR (dehydration)) OR (transparent tooth model)) OR (dyes)) OR (dye penetration method)) OR (spiral ct)) OR (micro CT)) OR (peripheral quantitative computed tomography)) OR (optical coherence tomography)) OR (tuned aperture computed tomography)) OR (diaphanization)) OR (Roentgenographic investigation))) AND (((((((((permanent dentition) OR (permanent teeth)) OR (human permanent teeth)) OR (molars)) OR (premolars)) OR (canines)) OR (incisors)) OR (maxillary)) OR (mandibular))*.

Study Selection And Data Extraction Process:

The database search showed 853 articles on PubMed, 283 articles on EBSCOhost, 429 articles from Google Scholar search and 239 articles through a hand search. In the first step of the screening process, Mendeley software (version 1803) was used for duplicates removal of the articles. After removing duplicates, 1252 articles were evaluated. In the second step of the screening process, 823 articles were excluded because they were determined to be irrelevant based on titles and abstracts. In the third step of the screening process, further 24 articles were excluded after a full-text analysis because they did not meet the inclusion criteria. Hence, the selection process resulted in 405 full-text articles. The entire study selection process is explained in the PRISMA flowchart.

Data Extraction And Management:

Two review authors (SS & NR) independently collected data using a specially designed data extraction form. Two review authors (SS & NR) had pilot-tested the data extraction form with a few articles and modified it as required before use. The data was extracted according to the following domains: Study Id, author, title, country, study type, number of teeth, tooth type, root canal anatomy studies, technique used.

Risk Of Bias Assessment In Individual Studies

The quality assessment of the selected studies followed the checklist for prevalence studies from the Joanna Briggs Institute (JBI) Critical Appraisal tool for use in systematic reviews(14). All the included studies were independently assessed by two evaluators, who scored each JBI question as yes (score 1), no (score 3), unclear (score 2) or not applicable. When there was no sample size calculation done in the study, we conducted our own sample size analysis using the following formula (15):

$n = Z2P(1-P) \div d2$

where,

n = sample size,

Z = Z statistic for a level of confidence,

P = expected prevalence or proportion (in proportion of one; if 20%, P = 0.2), and

d = precision (in proportion of one; if 5%, d = 0.05).

Expected prevalence or proportion for all the teeth categories is mentioned in the annexure.

The risk of bias for each question was categorized according to the score as 'high' (score 0), 'moderate/unclear' (score 1) or 'low' (score 2). Finally, 405 studies fulfilled the eligibility criteria and were included for qualitative synthesis.

RESULTS

The electronic database search resulted in 1553 articles, 853 in PubMed, 429 in Google Scholar, and 283 in EBSCO. Hand searching resulted in an additional 239 articles. A total of 1252 articles were screened after removing duplicates, out of which 823 were excluded and 429 remained eligible for reading the full text. Twenty-four articles were excluded for not meeting the inclusion criteria and a qualitative synthesis was performed for the remaining articles. The remaining 405 articles were submitted to the JBI critical assessment tool for assessment of their scientific merit. The mean JBI score of all the articles was 9.67. Only 1 article was categorised as "Low quality", 78 were categorised as "Medium quality", and 333 were in "high category".

The selected studies included data from at least 288478 teeth studied, of which, 206270 teeth were studied by CBCT, 30980 teeth were studied by clearing technique, 3616 teeth were studied by sectioning, 9027 teeth were studied by Micro CT, and 1191 teeth were studied by resin or plastic infiltration.

The most common method of studying canal anatomy was CBCT with 210 articles, followed by clearing technique with 80 articles, 2D radiography and Micro CT with 60 and 57 articles, respectively. Sectioning was performed in 13 articles, and plastic or resin models were used in 7 articles.

The commonest parameters studied were canal morphology, presence as well as morphology of MB2 canals in maxillary molars, C-shaped canal morphology in mandibular molars, presence of extra roots and canals, isthmuses, and racial characterisation of the study population.

DISCUSSION

A variety of methods has been used to study the root canal anatomy. One of the earliest attempts to study the internal anatomy of teeth was to inject a molten solution into the root canal and then observe it after complete decalcification of the tooth In this injection-moulded technique, a liquid is injected into the canals which hardens upon setting. The rest of the tooth is then decalcified completely by an acidic solution leaving a cast of the root canal system(16). If the liquid was viscous, it would not penetrate completely into all the intricacies of the canal anatomy, if it had a low surface tension, it would be too fragile upon hardening and break apart during retrieval. This technique is not much in use today, since better and non-invasive techniques are available. To overcome problems with the injection-moulded method, a technique for rendering teeth transparent was invented, which allowed visualisation of the canal system after injection of suitable dye such as India ink or methylene blue. Walter Hess and Ernst Zurcher injected vulcanised rubber into root canals of 2790 teeth and rendered them transparent. They observed that the canal anatomy was very complex and unlike their simple appearance on radiographs(17). Okumura used the clearing technique in the year 1927 to study the root canal anatomy of all human permanent teeth in a Japanese population (5). Clearing or diaphanization represents a way of studying the root canal anatomy without altering the canal system by way of forceful injection or instrumentation. In this technique, teeth are rendered transparent by decalcifying, dehydrating, and then replacing the space occupied by the water, with a transparent medium such as methyl salicylate. The clearing medium has a refractive index close to that of dentin, and therefore the tooth appears transparent. Clearing or transparency technique is a relatively easy and inexpensive technique that has been used in many studies and provides good detail of minute features such as location and position of apical foramina, intercommunications and anastomoses. It has value in education as well as research and many of the existing canal anatomy classifications have been developed using this technique. If the intention of a study is to study detailed anatomy of individual teeth, clearing or transparency technique may be employed. In the present systematic review, clearing technique was used in 80 articles. In these articles, number of roots, root canals and canal morphology was studied in 62 studies (77.50%). Number and location of apical foramen (10%), accessory and lateral canals (7.50%), apical delta (6.25) and inter canal communications (6.25) were mainly reported in the studies that used clearing technique method to study the root canal anatomy.

When comparing methodologies, clearing was the predominant in-vitro technique but recently CBCT has become an effective tool in successfully exploring the root canal anatomy and more contemporary studies using three-dimensional imaging systems have been performed. CBCT studies have been the most commonly performed in recent years – but this distinction of anatomical study vs prevalence

study is important – CBCT studies are usually performed to understand the prevalence of a particular canal anatomy type (18).

A summary table of the results is presented in Table 1. A total of 405 articles were extracted of which 210 articles used CBCT method to evaluate root canal anatomy. CBCT method was mostly used to detect number of roots, root canals and canal morphology (74.76%) followed by C shaped canal morphology (9.05%). No of roots, root canals and canal morphology was studied in 45 studies (75%) out of 60 studies that used 2d radiography and clinical techniques. Direction of canal curvature (6.67%), C shaped canal morphology (6.67%), extra roots and canals (6.67%) were some of the findings that were detected using 2D radiography method.

CBCT represents a method where large populations can be quickly surveyed for epidemiological studies, where population trends can be identified. This is helpful to identify racial as well as ethnic characterisation of the root canal systems in a particular population.

Table 1: Summary Table Of Study Findings

	CBCT		Clearing		2D Xray /Clinical		Sectioning		Micro CT		Others	
	N	%	N	%	N	%	N	%	N	%	N	%
Total studies and Characteristics	210	48.95	80	18.65	60	13.99	15	3.50	57	13.29	7	0.70
Total number of teeth studied	206310		31257		37901		3988		9067		1191	
No of roots, root canals or canal morphology	157	74.76	62	77.50	45	75.00	6	40.00	40	70.18	4	57.14
Isthmus	5	2.38	2	2.50	2	3.33	7	46.67	3	5.26	0	0.00
Direction of canal curvature	6	2.86	0	0.00	4	6.67	0	0.00	2	3.51	0	0.00
Accessory and lateral canals	4	1.90	6	7.50	1	1.67	0	0.00	1	1.75	1	14.29
Root wall thickness	6	2.86	1	1.25	0	0.00	0	0.00	1	1.75	0	0.00
C shaped canal morphology	19	9.05	2	2.50	4	6.67	2	13.33	4	7.02	1	14.29
Fused roots	2	0.95	0	0.00	0	0.00	0	0.00	1	1.75	0	0.00
Root length	3	1.43	1	1.25	1	1.67	0	0.00	0	0.00	0	0.00
Extra roots and canals	12	5.71	1	1.25	4	6.67	0	0.00	2	3.51	0	0.00
Apical delta	1	0.48	5	6.25	1	1.67	0	0.00	2	3.51	1	14.29
distance between orifices	5	2.38	0	0.00	0	0.00	0	0.00	0	0.00	1	14.29
Intercanal communications	0	0.00	5	6.25	1	1.67	0	0.00	0	0.00	0	0.00
Number and Location of apical foramen	0	0.00	8	10.00	2	3.33	1	6.67	2	3.51	1	14.29
Racial and ethnic characterisation	162	77.14	50	62.50	3	5.00	1	6.67	31	54.39	0	0.00
Dental anomalies	0	0.00	0	0.00	1	1.67	0	0.00	0	0.00	0	0.00
Root and canal width	0	0.00	0	0.00	0	0.00	1	6.67	0	0.00	0	0.00

Figure 1: Geographical Details Of Root Canal Anatomy Studies

Conventional radiography using intraoral periapical radiographs has also been used to study the root canal anatomy. It provides limited but useful information, and has been used in extracted teeth as well as clinically. It can provide information about the number and course of root canals and is easy to perform. It has been used in clinical studies along with visual observation with or without the aid of a dental operating microscope. Sixty studies reported using clinical observation and conventional radiography to study the root canal anatomy. The features most commonly identified were number of roots and root canals (75%), presence of extra roots and canals (6.67%), direction of canal curvature (6.67%) and C-shaped canal morphology (6.67%). Most often, viewing the lateral canals, apical deltas, and anastomoses is a challenge with radiography, including CBCT. These details can be viewed with micro-CT, but the disadvantage is that it is not readily available and is expensive.

Only 15 articles reported sectioning method to study root canal morphology. Out of which 40% studied no of roots, root canals and canal morphology. Sectioning method mostly detected isthmus (46.67%) followed by C-shaped canal morphology (13.33%), number and location of apical foramen (6.67%) and root and canal width (6.67%). With the advent of CBCT and micro-CT, 3-D visualisation in the form of axial sections and other planar sections, the sectioning method has generally gone out of favour. However, it may be used to provide information about canal shape, especially for isthmuses and C-shaped anatomy.

Micro CT was used in 57 studies to evaluate root canal anatomy. Maximum studies identified the number of roots, root canals and canal morphology. C-shaped canal morphology (7.02%) and isthmus (5.26%) were also identified using this technique. Racial characterisation (54%) was also one of the frequently studied characteristics.

A variety of other 3-dimensional techniques have been used in the past for studying the root canal anatomy. These are conventional computed

tomography (CT), spiral computed tomography (Spiral CT), peripheral quantitative computed tomography (pqCT), multidetector computed tomography (MDCT), optical coherence tomography (OCT), tuned aperture computed tomography (TACT). These represent techniques where either CBCT or micro-CT were not developed enough and were adapted from medical use for studying root canal anatomy.

Root canal studies have been performed all over the world. The parts with maximum studies are Asia, with the highest number of studies coming from the Middle east, South east Asia, East Asia, and South Asia, in that order. Europe, Africa, South America, North America, and Australia, in that order also have reported studies. Data seems to be lacking from large parts of Africa, Scandinavia, and Central Asia (Figure 1).

CONCLUSION:

The complexity of the root canal anatomy represents a challenge to endodontists if they are to successfully debride and disinfect the canal system. With the advent of 3-dimensional radiographic techniques such as CBCT and micro-CT, these methods have become the mainstay of root canal anatomy studies, especially as these techniques have become less expensive and more widely available. Certain techniques such as clearing are relevant even today as they provide excellent details on the intricacies of the canal system. Depending on the study characteristic to be studied, the appropriate method must be employed.

REFERENCES

1. Byström A, Sundqvist G. Bacteriologic evaluation of the efficacy of mechanical root canal instrumentation in endodontic therapy. European Journal of Oral Sciences 1981;89(4):321-328.
2. Nair PNR, Henry S, Cano V, Vera J. Microbial status of apical root canal system of human mandibular first molars with primary apical periodontitis after "one-visit" endodontic treatment. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology 2005;99(2):231-252.
3. Vera J, Siqueira JF, Ricucci D, Loghin S, Fernández N, Flores B, et al. One-versus two-visit endodontic treatment of teeth with apical periodontitis: a histobacteriologic study. J Endod 2012;38(8):1040-1052.
4. Versiani MA, Basrani B, Sousa-Neto MD. The root canal anatomy in permanent dentition. Springer; 2018.
5. Okumura T. Anatomy of the Root Canals**Read before the Section on Anatomy, Physiology, Materia Medica and Therapeutics at the Seventh International Dental Congress, Philadelphia, Pa., Aug. 23, 1926. The Journal of the American Dental Association (1922) 1927;14(4):632-636.
6. Weine FS, Healey HJ, Gerstein H, Evanson L. Canal configuration in the mesiobuccal root of the maxillary first molar and its endodontic significance. Oral Surgery, Oral Medicine, Oral Pathology 1969;28(3):419-425.
7. Vertucci FJ. Root canal anatomy of the mandibular anterior teeth. Journal of the American Dental Association (1939) 1974;89(2):369-371.
8. Gulabivala K, Aung TH, Alavi A, Ng YLL. Root and canal morphology of Burmese mandibular molars. International Endodontic Journal 2001;34(5):359-370.
9. Gulabivala K, Opasanon A, Ng YL, Alavi A. Root and canal morphology of Thai mandibular molars. International Endodontic Journal 2002;35(1):56-62.
10. Ng YL, Aung TH, Alavi A, Gulabivala K. Root and canal morphology of Burmese maxillary molars. International Endodontic Journal 2001;34(8):620-630.
11. Sert S, Aslanalp V, Tanalp J. Investigation of the root canal configurations of mandibular permanent teeth in the Turkish population. International Endodontic Journal 2004;37(7):494-499.
12. Versiani MA, Ordinola-Zapata R. Root canal anatomy: implications in biofilm disinfection. In: The root canal biofilm. Springer; 2015. p. 155-187.
13. Ahmed HMA, Versiani MA, De-Deus G, Dummer PMH. A new system for classifying root and root canal morphology. Int Endod J 2017;50(8):761-770.
14. Munn Z, Moola S, Riitano D, Lisy K. The development of a critical appraisal tool for use in systematic reviews addressing questions of prevalence. Int J Health Policy Manag 2014;3(3):123-128.
15. Naing L, Winn T, Rusli B. Practical issues in calculating the sample size for prevalence studies. Archives of orofacial Sciences 2006;1:9-14.
16. Fisher DE, Ingersoll N, Bucher JF. Anatomy of the pulpal canal: three-dimensional visualization. Journal of Endodontics 1975;1(1):22-25.
17. Hess W. The anatomy of the root-canals of the teeth of the permanent dentition, Part 1. . New York.: William Wood and Co.; 1925.
18. Martins JNR, Marques D, Silva E, Caramês J, Versiani MA. Prevalence Studies on Root Canal Anatomy Using Cone-beam Computed Tomographic Imaging: A Systematic Review. J Endod 2019;45(4):372-386.e374.