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CARES - A new three-dimensional coding system for classifying teeth with *dens invaginatus*

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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CARES - A new three-dimensional coding system for classifying teeth with *dens invaginatus*

Abstract

Aim: To establish a novel comprehensive three-dimensional coding system for the classification of teeth with *dens invaginatus* (DI) using cone beam computed tomography (CBCT) imaging.

Methodology: An initial draft classification of teeth with DI was developed by the project directors and steering group based on the interpretation of CBCT images. A group of 26 global experts then provided their perspectives on the classification via a consensus-building online Delphi process. Following the achievement of consensus, six endodontists independently examined CBCT images of teeth with DI to evaluate the reliability of the draft classification. Inter-rater reliability was employed to ascertain the agreement among the six assessors and intra-rater reliability was assessed following the re-evaluation of the identical CBCT images three weeks later. The steering group then revised and finalized the classification.

Results: The online Delphi process was completed in a single round with a 100% response rate. The inter-rater reliability score of 0.89 and the intra-rater reliability score of 0.88 revealed “almost perfect” agreement among and within the evaluators. The final CARES classification of teeth with DI includes five domains: Communication (C), cross-sectional Anatomy (A), Root formation (R), vertical Extent (E), and Supplementary features (S).

Conclusion: The three-dimensional CARES classification system provides stakeholders with a consistent and unambiguous method of categorising teeth with DI. The system has the potential to enhance the precision of diagnosis and clinical decision-making in the management of DI and ensures clinicians can communicate more accurately with patients and other healthcare professionals.

Keywords: Cone beam computed tomography, *dens invaginatus*, endodontics, root canal, CARES classification

Introduction

Dens invaginatus (DI) is a developmental anomaly of teeth characterized by the infolding of the enamel organ into the dental papilla prior to the completion of calcification (Hülsmann, 1997). A meta-analysis reported that the global prevalence of individuals with DI is approximately 7%, with the maxillary lateral incisor being the most commonly affected tooth with a unilateral prevalence of approximately 5%, as determined by cone beam computed tomography (CBCT) (Alves Dos Santos et al., 2023).

The classification system of DI developed by Oehlers (1957) categorises the anomaly into three primary types based on its appearance on conventional two-dimensional (2D) periapical radiographs. Even though Oehlers' classification is widely accepted and has been adopted universally, it was developed based on the appearance of invaginations on periapical radiographs that only provide a limited two-dimensional representation of their often complicated three-dimensional (3D) morphology. Features that determine the treatment of teeth with DI such as communication of the invagination with the root canal, periodontium or both, displacement of the main canal by the invagination, and presence of associated features cannot be precisely assessed using periapical radiographs. This lack of a full assessment of the anomaly and surrounding tissues is likely to have a negative effect on treatment planning, management approaches, and clinical outcomes.

The limitations inherent in 2D imaging adversely affect current classification systems for DI, which are unable to: a) accurately depict the spatial extent or diversity of the invagination; b) furnish adequate guidance for treatment planning, thereby restricting their clinical usefulness; and c) deliver a clear description suitable for professional discussion among clinicians. On the other hand, CBCT provides a unique benefit in the diagnosis and classification of DI, as well as its treatment, which includes the utilization of 3D guides for access cavity preparation (Capar, 2015; Yalcin et al., 2022; Abella Sans et al., 2025).

The advent of CBCT has revolutionized the diagnosis and detailed interpretation of complex dental anomalies and has become an essential tool when evaluating the extent of an invagination, its communication with adjacent tissues, and the presence of pathosis

(Alkadi et al., 2021). Indeed, several studies have offered descriptive or treatment-focused refinements of the classification of DIs based on radiographs and CBCT; however, none offered a fundamental revision of Oehlers' system to take into account the finer details of their 3D morphology that can be detected when using CBCT images (Vincent-Townend, 1974; Schulze & Brand, 1972; Hülsmann, 1997; Kritika et al., 2022; Gul et al., 2020; Zhu et al., 2017).

There is an increasing demand for a contemporary classification system based on CBCT imaging that precisely illustrates the 3D morphological variations of the invagination. A system of this nature will not only enhance the precision of diagnoses but also offer support for clinical decision-making, aid in treatment planning and promote uniformity in the reporting of studies evaluating the outcome of treatment. The objective of this project is to establish a novel, standardized, and comprehensive 3D classification system for teeth with DI based on CBCT imaging, which has the potential to improve diagnostic precision, enhance communication among clinicians, support treatment planning, and promote the reproducibility of research.

Methodology

The protocol for the present investigation has been published (Nagendrababu et al., 2026). Ethical approval was obtained from the local institutional review board (REC-25-09-01-01-F).

Phase 1: Setting up of a steering committee

The project directors (VN, PD) established a steering committee with overall responsibility for managing the project.

Phase 2: Developing draft classification

The steering committee drafted an initial classification system for teeth with DI based on CBCT imaging using criteria that were consistent, reproducible, and aligned with the diagnosis, treatment, and prognosis of DI.

Phase 3: Validation of the classification

The steering committee formed a panel of 26 experts, comprising academic or clinical endodontic specialists (n=17), oral radiology specialists (n=3), endodontic postgraduate students (n=3), and general dental practitioners (n=3), to provide their perspectives on the clarity, relevance, and utility of the classification through an online Delphi process. Table 1 provides a list of the eligibility criteria that experts satisfied in order to participate in the Delphi process.

Each member of the panel offered their anonymous and independent evaluation of the clarity, relevance, and specific wording of each domain / description within the proposed classification system, utilizing a dichotomous scale (yes/no) and a 9-point Likert scale (1: definitely exclude to 9: definitely include). Each domain in the classification was included when it received a score of 7–9 from at least 70% of members and a score of 1–3 from fewer than 30% of members. Domains were excluded if more than 70% of members assigned a score of 1–3, and fewer than 30% of members assigned a score of 7–9. The panel of reviewers was given the opportunity to suggest changes to the wording of each domain and propose new domains for the classification.

Phase 4: Reliability of the classification

Following the results of the Delphi process, a reliability analysis of the classification was conducted using the CBCT images of two teeth with DI. The CBCT images had been archived at a university hospital and private dental practice and had been prescribed for purposes unrelated to the study. Thus, the reliability analysis did not involve subjects undergoing a CBCT scan. In order to guarantee blinding and eliminate potential identification bias, all CBCT images were anonymized prior to the reliability test.

Each of the CBCT images included in the reliability process depicted a distinct anatomical feature of DI with adequate image quality. After the project leaders selected the preliminary images, the members of the steering committee with expertise in DI and CBCT interpretation independently reviewed and assessed the images for their suitability. The final set of images was authorized for use in the reliability assessment following a consensus discussion.

In total, six endodontists independently assessed the CBCT images in the reliability test. All had a minimum clinical experience of five years and were familiar with the interpretation of CBCT images. Prior to the test, the project director (VN) emailed standardized instructions and the draft 3D DI classification system to all assessors to guarantee a consistent understanding of the classification criteria. The CBCT images were sent to assessors via Google Form, and each assessor was requested to provide a code for all five domains within the proposed classification system. To reduce variability caused by time pressure, no time limits were set for the test, which also allowed the individuals sufficient time to fully evaluate the CBCT images.

To assess the reliability of the proposed 3D classification for DI, intra-rater and inter-rater reliability assessments were conducted. In order to evaluate intra-rater reliability, each observer re-evaluated the identical set of CBCT images after a three-week washout period, with the objective of reducing memory bias and recall. The CBCT images were re-arranged to preclude the recognition of image order prior to the second assessment.

Phase 5: Finalising and dissemination of the classification

Based on the feedback obtained through the Delphi process and reliability testing, the steering committee revised and formally approved the classification of teeth with DI.

Statistical analysis

Six independent assessors evaluated the two cases of DI that included a total of 10 images for each. Inter-rater reliability was assessed using Fleiss' Kappa whereas intra-rater reliability was assessed using unweighted Kappa. All statistical analyses were performed using the "irr" package (version 0.84.1; R Foundation for Statistical Computing, Vienna, Austria) in R software (version 4.5.3; R Foundation for Statistical Computing, Vienna, Austria). A score of 0.81-1 is considered as "almost perfect" agreement (Landis & Koch, 1977).

Results

Online Delphi process

The online Delphi process was completed in a single round and incorporated input from 26 participants from around the world, achieving a 100% response rate. Supplementary Table 1 presented the results of online Delphi exercise. Five domains in the classification received scores of 7–9 from more than 70% of members; therefore, they were included in the classification and eligible for the reliability test. Since a 100% response rate and immediate, high consensus (>70% scoring 7–9) was achieved in the first round, a second round was methodologically redundant because the consensus criteria were already fully met.

In addition to scoring each domain, participants were encouraged to provide free text feedback on the wording of each category to improve clarity. Following the feedback, minor refinements were made by the steering group, including clarification or clarity of domain definitions and wording for improved interpretability, without altering the overall framework. Disagreements were minimal and resolved through steering committee consensus prior to finalisation.

Reliability test

The inter-rater reliability test demonstrated “almost perfect” agreement among the six endodontists (0.89). The intra-rater reliability also demonstrated “almost perfect” agreement (0.88), indicating that the assessments of individual assessors were stable and reproducible over time.

CARES classification system

The new CARES system for classifying teeth with DI is presented in Table 2 and schematic illustrations are provided in Figure 1. The classification is based on five domains where “CARES” stands for Communication (C), cross-sectional Anatomy (A), Root formation (R), vertical Extent (E) and Supplementary features (S). As an example, a tooth with DI having the following features would be coded as C3-A0-R1-E2-S1: Invagination communicating with both root canal and periodontium (C3), invagination not displacing or deforming the root canal (A0), tooth with a immature root (R1), invagination extending into the root (E2), and periradicular pathosis associated with the root canal (S1).

Discussion

Oehlers' classification vs CARES

The classification system of Oehlers (1957) is based on periapical radiographs and is focused mainly on the apical extent of the invagination. Clearly, the three-dimensional complexity and anatomical variations that directly influence treatment planning, for example communications with the root canal or periodontium, lateral displacement or deformation of the root canal, and prognosis are not entirely captured by such a system. In contrast, the CARES classification is based on CBCT imaging and enables a comprehensive three-dimensional assessment of teeth with DI as well as associated pathosis. As a result, adopting the CARES system allows clinicians to categorise several additional parameters, including the communication of the invagination with the root canal and/or periodontium, the spatial relationship between the root canal and invagination, the degree of root development (mature or immature), and associated periradicular and periodontal pathosis. In summary, CARES provide clinicians with a simple, structured, reproducible framework that includes a clinically meaningful anatomical representation of teeth with DI, thereby facilitating diagnosis and treatment planning as well as better communication with patients and other stakeholders (Table 3).

Domains in the CARES system

The communication domain (C) is of particular significance, as invaginations that communicate with the root canal system and/or the periodontium directly affect routes of infection and thus the development of pathosis. Therefore, including the C component enhances the clinical applicability of the system by explicitly categorizing these patterns of communication and thus the selection of appropriate therapeutic strategies. For example, treating the invagination alone while maintaining the viability of the pulp (Abella Sans et al., 2026). Given the 2D basis of Oehlers classification, assessment of potential communications is only possible in the mesio-distal plane, not in the buccal-lingual/palatal plane.

The cross-sectional anatomy domain (A) defines whether the invagination deforms or displaces the root canal from its expected shape and alignment. This distinction is essential for the preparation of access cavities to the root canal and/or invagination, their negotiation and filling. The information also informs the optimum

management technique and whether sophisticated techniques, such as guided access cavities are necessary. For example, in a case of Type IIIa DI in maxillary lateral incisor, CBCT evaluation aided the measurement of the cross-sectional dimension of the invagination to select the drill size for guided endodontics (Abella Sans et al., 2026).

Treatment considerations are further informed by the domain of root development status (mature vs. immature) (R). Immature teeth with open apices and apical pathosis associated with pulp disease may benefit from regenerative procedures or apexification, while mature teeth typically require root canal treatment. Although the Oehlers classification allows an approximate determination of the stage of root development, some cases require a more detailed and precise analysis. As an example, a case report of a tooth exhibiting an immature root and Oehlers Type II invagination demonstrated that regenerative endodontic treatment of the immature root was effectively achieved by accessing the canal through the invagination (Martin et al., 2024).

CARES is also aligned with biologically meaningful anatomical boundaries that influence pulpal and periodontal involvement by incorporating the vertical extent of the invagination (E) into a simple binary classification. Defining the level of vertical extent of the invagination into several categories as in previous classification systems (Oehlers, 1957) does not impact their management, particularly since on periapical radiographs it is not possible to accurately define the extent of the invagination. Thus, the classification in this domain is restricted only to whether it extends up to CEJ, which warrants a conservative approach to explore the invagination and consider its restoration, or whether it extends into the roots, which may result in more complex procedures. Invaginations extending into the root with periodontal communications and bone defects may need adjunctive surgical periodontal procedures. Consequently, the integration of the extent of the invagination as a distinct domain improves the precision of diagnostics and the quality of clinical decision-making in the management of teeth with DI.

Finally, the incorporation of a supplementary features domain (S) recognizes that the classification should not only be morphological but also be aligned with disease, manifesting in radiographic features. Periapical or periodontal pathosis influences the

prognosis and management of the condition. The absence of supplementary features (S0) suggests that the tooth is biologically healthy even though it is structurally complex. In contrast, periradicular pathosis may be linked to the root canal system (S1), the invagination (S2), or both (S3), indicating distinct pathways of microbial ingress and disease progression. This difference allows customized treatment, which prevents overtreatment and improves outcomes by addressing the underlying cause of infection rather than a uniform approach. In certain instances, diagnostic uncertainty is acknowledged in teeth where the origin of periradicular pathosis cannot be defined (S4) and explains why that category was included. Pathological marginal bone loss, which is also included as a supplementary feature (S5), accounts for concomitant periodontal involvement often associated with teeth with DI, which has the potential to influence the long-term outcome and management protocol of teeth with DI.

Limitations

- i) CBCT image quality is influenced by voxel size, field of view, and artefacts, which can mask fine anatomical details. Consequently, intricate details may be either underestimated or missed.
- ii) The routine use of CBCT in all suspected DI cases may be restricted by its availability, cost considerations and concerns over radiation exposure. Consequently, the applicability of this classification is restricted to environments where CBCT is readily accessible and clinically justified.
- iii) It is possible that some teeth with highly complex DI morphology may be impossible to categorize using CARES. Therefore, refinements to CARES may be necessary in future with experience and as new data becomes available.
- iv) Although the simple five-domain structure is intended to improve comprehensiveness, its ease of use in routine clinical practice may be compromised by its increased complexity. Training and calibration among clinicians will be necessary to guarantee consistent interpretation in order to evaluate all domains.
- v) The reproducibility and utility of the classification may be affected by variability in CBCT interpretation among clinicians with differing levels of

training and experience, for example, undergraduate and postgraduate students, general practitioners and endodontists.

- vi) The CARES classification of DI morphology does not include clinical features such as the final diagnosis of the state of the pulp tissue in root canals, carious lesions, and the contents of invaginations, all of which may have an impact on treatment strategy and prognosis.
- vii) The reliability test was performed based on two representative cases of DI selected to cover different morphological characteristics and levels of complexity. Therefore, the reliability findings should be interpreted with caution and validated in future studies using a larger and more diverse set of cases. Although excellent inter- and intra-rater agreement was achieved, the small sample size may limit generalizability of the results. However, it is worth noting that independent clinicians achieved “almost perfect” agreement ($\kappa = 0.89$) without prior training.

Future directions

- i) Studies with larger datasets representing the full morphological spectrum of DI are required to validate the reproducibility of the CARES system when used by clinicians with differing levels of experience, other dental specialist and dentists from different geographic or educational backgrounds. Consequently, multicentre studies involving a variety of clinical populations and practice settings are required to externally validate the reproducibility, usability, and generalizability of the proposed system in real-world environments.
- ii) There is potential for CARES to be integrated into CBCT-based treatment planning software to facilitate optimum management strategies.
- iii) Future studies should focus on developing simplified clinical workflows or decision-support tools and evaluate the efficiency and usability of the system in real-world clinical settings.
- iv) The proposed CARES coding system can be integrated with artificial intelligence-based image analysis. The application of methods for machine learning to CBCT imaging could facilitate the automated detection, objective classification, and

prediction of treatment complexity, thereby enhancing the consistency of diagnostics and clinical decision-making.

Conclusion

The new CARES coding system for classifying teeth with DI is based on five domains: Communication (C), cross-sectional Anatomy (A), Root formation (R), vertical Extent (E) and Supplementary features (S). The high inter- and intra-rater reliability indicates that adopting CARES will be straightforward, and facilitate the standardization of documentation and communication among clinicians, postgraduate and undergraduate students, and researchers.

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Legends

Table 1: Eligibility criteria for participation in the Delphi process

Table 2: CARES - A new 3-dimensional coding system for classifying teeth with *dens invaginatus*

Table 3: Comparison of the Oehlers (1957) and CARES classification systems for *dens invaginatus*

Supplementary Table 1: Results of online Delphi exercise

Figure 1: CARES system for classifying teeth with *dens invaginatus*

Table 1: Eligibility criteria for participation in the Delphi process

Category	Eligibility criteria
Specialist endodontists	A minimum of five years of experience as academics or clinicians, or publication of at least one article related to DI
Specialist oral radiologists	A minimum of five years of experience in the interpretation of CBCT images
General dental practitioners	A minimum of ten years of clinical experience
Endodontic postgraduate students	In the 2 nd or 3 rd year of their endodontic programme

Table 2: CARES - A new 3-dimensional coding system for classifying teeth with *dens invaginatus*

Domains	Code	Description
Communication (C)	C0	Invagination does not communicate with the root canal or periodontium
	C1	Invagination communicates only with the root canal
	C2	Invagination communicates only with the periodontium
	C3	Invagination communicates with both root canal and periodontium
Cross-sectional anatomy (A)	A0	The invagination does not displace or deform the root canal
	A1	The invagination does displace or deform the root canal (e.g. C- shape, comma shape etc)
Root formation (R)	R1	The root of the tooth is immature
	R2	The root of the tooth is mature
Vertical Extent (E)	E1	Invagination extends only within the crown and not beyond the cemento-enamel junction (CEJ) into the root
	E2	Invagination extends into the root
Supplementary features (S)	S0	Absence of supplementary features
	S1	Periradicular pathosis associated with the root canal
	S2	Periradicular pathosis associated with the invagination
	S3	Periradicular pathosis associated with both invagination and root canal
	S4	Periradicular pathosis of unknown or unclear origin
	S5	Marginal bone loss

Table 3: Comparison of the Oehlers (1957) and CARES classification systems for *dens invaginatus*

Feature / Parameter	Oehlers (1957)	CARES (2026)
Mode of assessment	Two-dimensional periapical radiographs	Cone beam computed tomography.
Classification structure / number of domains or types	Three types of DI based on morphology of the invagination (I, II, III)	Five independent domains assessed separately and combined to give a holistic description of a tooth with DI: C (Communication), A (cross-sectional Anatomy), R (Root development), E (vertical Extent), S (Supplementary features)
Basis of classification	Radiographic depth of extent and depth of invagination from the crown into the root and its communication with the pulp and periodontal tissues.	Multi-domain: (C) communication of invagination with root canal and/or periodontium; (A) spatial relationship / cross-sectional displacement of root canal; (R) root development status (mature vs. immature); (E) vertical extent (binary: crown-only vs. root extension); (S) supplementary features including periradicular pathosis and marginal bone loss
Communication domain (invagination-to-canal / PDL)	Communication between the invagination, dental pulp, and periodontal tissues	Explicit dedicated domain (C): categorizes whether invagination communicates with root canal system and/or periodontium; aids in assessing infection pathways and treatment selection
Cross-sectional anatomy / spatial relationship	Not addressed	Explicit dedicated domain (A): defines whether invagination deforms or displaces root canal from expected shape; aids in access cavity design, negotiation, filling, and need for guided access techniques
Root development status	Not addressed	Explicit dedicated domain (R): binary classification of mature vs. immature root. Identifies immature teeth with open apices that aids treatment planning, e.g., use of regenerative procedures or apexification
Vertical extent of invagination	Core of classification: Type I = crown; Type II = root blind sac; Type III = through root	Explicit dedicated domain (E): binary classification (crown-only vs. root extension); avoids unnecessary subdivision since extent alone does not have an impact on management
Periradicular / periodontal pathosis	Not defined.	Explicit dedicated domain (S - Supplementary features): S0 = no pathosis (biologically healthy); S1 = pathosis linked to root canal; S2 = pathosis linked to invagination; S3 = pathosis linked to both; S4 = origin unknown (diagnostic uncertainty acknowledged); S5 = pathological marginal bone loss. Allows targeting of specific treatment plans.
Coding system	Roman numerals	Detailed Alpha-numeric
Treatment guidance provided	Not provided	Does not directly indicate treatment options, however, will give understanding of: access design (A domain), choice between RCT vs. regeneration (R domain), selective vs. combined treatment (C and S domains), and surgical vs. non-

		surgical approach (E domain). Structured framework facilitates patient communication and inter-clinician communication
Limitations	Too simple for complex cases	More complex, requires CBCT
Strength	Simple and universally known	Comprehensive and anatomically relevant classification

Supplementary Table 1: Results of online Delphi exercise

Domains	Responses received			Inclusion /Exclusion in the classification
	Score 7-9 (%)	Score 4-6 (%)	Score1-3 (%)	
Communication (C)	92*	4	4	Included
Cross-sectional anatomy (A)	81*	8	11	Included
Root formation (R)	88*	4	8	Included
Vertical Extent (E)	88*	4	8	Included
Supplementary features (S)	88*	8	4	Included

* Domains received scores of 7–9 from more than 70% members; therefore, they were included in the classification.

C A R E S

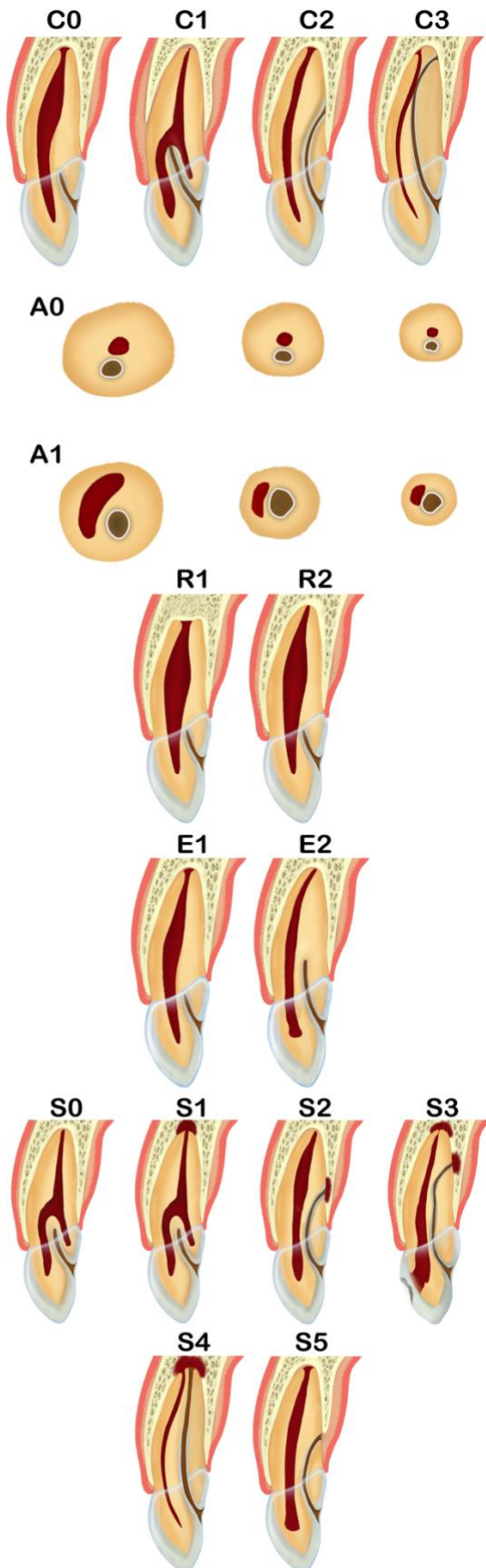


Figure 1