VARIATION IN THE ANATOMY OF TEETH WITH "C" CANALS: A LITERATURE REVIEW

VARIAÇÃO NA ANATOMIA DE DENTES COM CANAIS "C": UMA REVISÃO DE LITERATURA

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ABSTRACT

This study aims to present, through a literature review, the variations of C-shaped canals and treatment protocols for infected teeth. The literature review was developed using publications in English between 2015 and 2025. The results showed that C-shaped canals represent a complex anomaly of the internal morphology of teeth, predominantly found in lower second molars. Diagnosis by conventional radiographic methods is often insufficient, with identification often only being made after access to the pulp chamber. Treatment failure can occur due to the difficulty of completely sanitizing complex areas, such as isthmuses, and the inability to locate all extensions of the canal system, requiring in-depth knowledge of their anatomical variations and rigorous preoperative planning to achieve successful endodontic therapy. Cone beam computed tomography (CBCT) is essential for accurate diagnosis and three-dimensional visualization of these complex anatomies. In addition, the use of appropriate instrumentation and filling techniques that ensure complete sealing of the canal system, including the isthmuses, are crucial for disinfection and a favorable prognosis.

KEYWORDS: anatomy; failure; endodontic treatment.

1. INTRODUCTION

Failure of Hertwig's epithelial sheath fusion during embryonic development can result in the formation of complex interconnections between root canals, culminating in a C-shaped root canal configuration [1]. This anatomical variation can be observed in cross-sections of the root and represents a significant clinical challenge by making root canal disinfection more difficult, which can impact the prognosis of endodontic treatment[2].

The morphology of the C-shaped canal is unusual and features openings through the pulp chamber floor that lead to a band-shaped conduit with a 180-degree arc that begins at the mesio-lingual line and expands around the vestibular to the distal portion of the pulp chamber[3]. For a better understanding of the morphology of the "C" canal, different classifications have been established. According to Cooke[4], C-shaped root canals can be classified into two main types: (1) molars that have a continuous C-shaped band and (2) molars that have three distinct canals below this band. However, with research being conducted over time, researchers Melton, Krell, and Fuller[5] stated that teeth with "C" morphology may exhibit different anatomical patterns. However, with research being conducted during this time, researchers Melton, Krell, and Fuller[5] stated that teeth with a "C" morphology can exhibit different anatomical patterns. Thus, Melton, Krell, and Fuller[5] established a classification of the canals, the main ones being: Type I: has a continuous "C" shape, Type II: has a semicolon-like configuration, and Type III: has two or three separate root canals. Gao[6] also proposed a radiographic classification for C-shaped root canals, dividing them into three main categories: Type I (fusion): characterized by a conical or square root that fuses mesially and distally; Type II (symmetrical): has a conical or square root, but unlike type I, it occurs distinctly, and Type III (asymmetric): characterized by a conical or square root with an elongated isthmus in the bifurcation region.

In this regard, studies point to a higher prevalence in lower second molars. One of the methods for studying prevalence is through population surveys, as shown by the results in East Asian groups, which demonstrate higher rates in the Chinese (31.5%) and Korean (32.7-31%) populations. At this point, it can be observed that, over time, technological advances have transformed endodontics, providing better resources for dealing with the complex anatomy of the pulp system, such as the introduction of computed tomography, which allows the acquisition of images of the root canal system. technological advances have transformed endodontics, providing better resources to deal with the complex anatomy of the pulp system[9], such as the introduction of computed tomography, which allows detailed three-dimensional images to be obtained, optimizing anatomical evaluation and offering diagnostic precision. One of the advantages of this technology is the ease of identifying variations[10].

Endodontic treatment of C-shaped canals is a major challenge in clinical practice, considering that when conventional instrumentation is poorly performed, there are risks that can result in bacterial infection niches that can lead to treatment failure[11]. After an accurate diagnosis, performing quality endodontic treatment requires greater technical precision and knowledge of anatomy, given the anatomical complexity of root canals. Therefore, for endodontic treatment to be successful, it is essential to combine knowledge of anatomical variations with the different types of instruments required and the application of advanced technologies, such as computed tomography. Mastery of these aspects, combined with the use of modern technological resources, enables a more accurate analysis of the internal structure of the teeth and contributes to more effective and safer treatment. The integration of this knowledge into clinical practice reflects the advancement of dentistry and the constant search for improved therapeutic results, ensuring a more individualized and efficient approach for each patient.

Micro-CT is an important research tool in the analysis of anatomical variations and identification of C-shaped canals, as its technology reproduces high-resolution images in three dimensions, analyzing images of the teeth from the external to the most internal structure. Finally, technology has promoted a true evolution in dentistry, enabling significant improvements in endodontic treatments and considerably reducing the chances of failure. Given this, this study aims to present, through a literature review, the variations of C-shaped canals and treatment protocols for infected teeth.

2. MATERIAL AND METHODS

This study consists of a literature review based on publications in English between 2015 and 2025 and classic articles on the subject. The databases used were PubMed and Google Scholar, in which we used the descriptors C-shaped canal, C-shaped root canal, and C-shaped canal system. The inclusion criteria used were articles in English published between 2015 and 2025 that investigated endodontic treatment in C-shaped canals in vitro or in vivo. Case report articles and articles published before the mentioned period were excluded.

3. LITERATURE REVIEW

Dental pulp is connective tissue located in the pulp cavity, which includes the pulp chamber and root canal. This tissue is composed of blood vessels, lymphatic vessels, nerve fibers, and various specialized cells, including odontoblasts, which contain characteristics unique to pulp compared to other connective tissues in the body[14]. Understanding the anatomy of root canals is essential for successful endodontic treatment. The literature emphasizes the complexity of this system, which includes accessory canals, lateral canals, and apical deltas that can directly affect the prognosis of the procedure[15]. The morphology of root canals, including quantity, location, direction, and shape, plays a key role in the effectiveness of therapy and requires identification[16].

Pathological changes in dental pulp usually result from inflammatory processes caused by infections. Infection can lead to symptoms such as reversible pulpitis, irreversible pulpitis, and pulp necrosis. These conditions can be caused by microorganisms, chemical agents, or inappropriate mechanical trauma, making endodontic treatment essential for functional recovery of the tooth. If conventional instrumentation is poorly performed, there is a risk of root perforation or tearing, which can result in niches of bacterial infection in the periapical region. Root canal treatment methods and “C” indicate the need for smaller caliber instruments and strict disinfection protocols to minimize errors and ensure decontamination[19].

Successful endodontic treatment requires precision in technique and patience, especially due to the anatomical complexity of root canals. Structures such as sharp curves, narrowings, and branches hinder instrumentation and visibility, requiring technical skills from the professional. When the canals are straight, the application of the principles established by Schilder *et al*. (1974) becomes more predictable. However, the presence of curvatures increases complexity, raising the risk of deviations, perforations, and step formation[17].

C-shaped canals

The C-shaped canal gets its name from the morphology of its root and root canal cross sections, which resemble the letter “C” [21]. Unlike other molars with distinct canal entrances, the floor of the pulp chamber reveals a band-shaped conduit with a 180-degree arc, starting at the mesio-lingual line and expanding around the vestibular to the distal end of the pulp chamber[22]. The “C” canal was first described by Cooke and Cox *et al*. (1979) [4]. This variation results from a failure in the fusion of Hertwig's epithelial sheath during embryonic development, generating complex connections between the root canals[21]. The main feature of this anatomy is the interconnection between two or more canals, forming a continuous isthmus[21]. They show that this morphology occurs more frequently in the lower second molars[23], resulting from the fusion of the mesial and distal roots, resulting in a root groove and a canal with a configuration similar to that of an isthmus[24].

The lower second molars have anatomical peculiarities, with an average length of 22.5 mm. In most cases (65-70%), they have three canals, although variations such as two canals (10-16%) or four canals (5-10%) are also reported. The mesial root often contains two canals, which may open into one or two foramina, while the distal root usually has a single canal. In addition, the C-shaped canal is a common variation associated with root fusion, occurring in 2 to 8% of cases.

Curved canals, such as C-shaped ones, require special care due to the risk of perforations, path deviations, and step formation. Detailed knowledge of their anatomy and categories is essential to ensure successful endodontic treatment. The anatomical variation of "C" canals has a more significant influence on the form of preparation than the instrumentation itself[27]. According to Al-Fouzan K *et al.* (2017) [25], extensive areas were identified that were not mechanically treated when using rotary and manual techniques in these canals. To optimize debridement of roots with this morphology, some authors suggest combining different instrumentation systems and techniques. In the case of modeling teeth with C-shaped canals, it is recommended to instrument the fissure area and, if necessary, model the isolated canal separately[28].

Geographic variations

The prevalence of the "C" canal varies according to the population studied. Four anatomical variations are common in C-shaped canals; the location of these variations may differ between different population groups, and there is a higher prevalence in Asian populations[8].

Table 1. Geographic variation.

Population	Percentage (%)
Chinese	31,5%
Koreans	32,7% e 31,3%
Northern Italy	6,72%
Subpopulation of India	7,5% a 2%

Prevalence of C-shaped canals (Singh *et al*. 2022).

Variations between genders

Based on analyses from the study by Shaikh *et al***.** (2024) [29], a relationship was observed between gender, number of root canals, and C-shaped canals in the lower second molars. Thus, out of 200 molars, this study observed 15 C-shaped canals, with an approximately equal distribution between men and women[29]. The highest percentage of bilateral canals was in women, at 42.86%, and the highest percentage of unilateral canals was in men, at 75%[29].

Table 2: Gender differences

Gender	Unilaterais	Bilaterais
Women (n:8)	2 (25%)	6 (75%)
Men (n: 7)	3 (42,86%)	4 (54,14%)

Classification of "C"-shaped canals

According to Cooke and Cox *et al.* (1979) [4], C-shaped root canals can be classified into two main types: (1) molars that have a continuous C-shaped band and (2) molars that have three distinct canals below this band. Several classifications have been proposed to better understand this root morphology.

The first descriptions were presented by Manning *et al.* (2018) [27] and later modified by Melton, Krell, and Fuller *et al.* (1991) [5], who improved the description of root morphology and C-shaped canals, but this classification did not clearly differentiate the categories. Both considered only the appearance of the root canal opening, without describing the anatomical variations along the length of the root. Melton, Krell, and Fuller *et al.* (1991)[5] stated that teeth with "C" morphology may exhibit different anatomical patterns, both externally in the root and internally in the root canals. Subsequently, new classifications were developed by Fan[28] (2004), Gao *et al*. (2006)[6] and Al-Fouzan *et al*. (2017)[25], with more detailed descriptions.

Based on the analysis of 15 lower molars of patients aged between 18 and 40 years, they established a classification for "C" canals, consisting of five main types[26]:

Type I: has a continuous "C" shape, without separations or divisions.

Type II: has a semicolon-like configuration, resulting from the interruption of the "C" contour, but with angles α and β greater than 60°.

Type III: has two or three separate root canals, with angles α and β less than 60°.

Type IV: has a single oval or circular canal and may have two distinct rounded canals.

Type V: has an absence inside the canal that is visible in the section

Gao *et al.* (2006) [6] proposed a radiographic classification for C-shaped root canals, dividing them into five main categories:

Type I (fusion): characterized by a conical or square-shaped root, crossed by a longitudinal radiolucent line that separates it into mesial and distal portions. Near the apical foramen, there is fusion of a mesial canal and a distal canal, forming a single main canal before its exit.

Type II (symmetrical): has a conical or square root, also with a longitudinal radiolucent line that divides it into mesial and distal parts. However, unlike Type I, the mesial and distal canals follow independent trajectories toward the apex without joining.

Type III (asymmetric): characterized by a conical or square root with a longitudinal radiolucent line separating the mesial and distal portions. In this type, there is a mesial canal and a distal canal, the latter having an elongated isthmus in the bifurcation region and overlapping the radiolucent line before continuing toward the apex, while the mesial canal maintains an independent path.

Type IV (partial fusion): presenting a "C" canal functioning at root levels and separated at others.

Type V (degenerate/obliterated): refers to morphology in which the "C" pattern is absent or minimal.

As shown in Figure 1, C1 represents channel type I (fusion), C2 represents channel type II (symmetrical), C3 represents channel type III (asymmetrical), C4 represents channel type IV (partial fusion), and C5 represents channel type V:

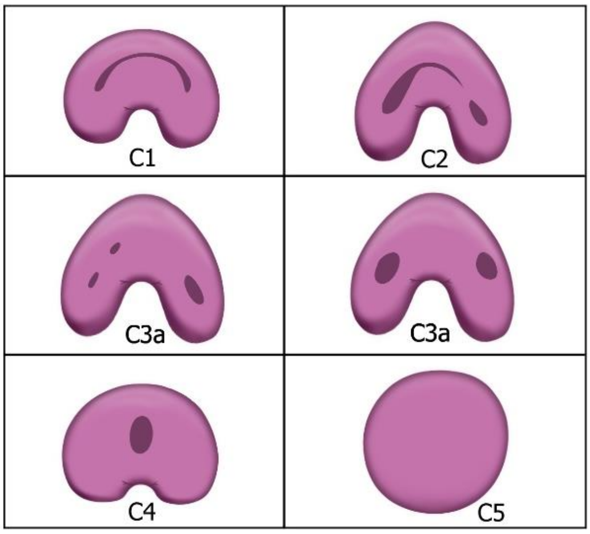

Figure 1: Representation of channel configurations in "C".

Technological advances in microtomography

Over time, technological advances have transformed endodontics, providing better resources for dealing with the complex anatomy of the pulp system. The introduction of computed tomography was equally crucial, allowing detailed three-dimensional images to be obtained, which optimized anatomical evaluation and diagnostic accuracy in endodontics[31].

Computed microtomography is a research tool that represents a significant advance, as it enables the reconstruction of samples on a micrometric scale and analyses using axial sections that cross the cervical, middle, and apical thirds, contributing to the analysis of dental anatomy, chemical-mechanical preparations, and endodontic retreatment. The main advantage of this technology lies in obtaining detailed images, facilitating the identification of anatomical variations, such as "C" canals in lower molars[32].

Working length of C-shaped canals

To establish the working length in a tooth with a C-shaped endodontic anatomy, three K-type manual endodontic instruments (15, 20, and 25) are used, one in the mesiolingual canal and two at the mesial and distal ends of the C-shape, obtaining a single foraminal exit[33]. It is stated[21] that the working length should be measured using an apical locator and confirmed with pre-existing CBCT information

Instrumentation

Although manual instrumentation is widely used, it may not be sufficient for cleaning the C-shaped canal, resulting in steps, perforations, and instrument fractures[34]. Thus, motor-driven nickel-titanium instruments provide good cleaning capacity compared to manual instruments, greater apical control of the instruments, and one of their greatest advantages is greater flexibility, facilitating canal cleaning[35]. Instrumentation can be performed using K files or 4% and 6% niti-rotary files if necessary[21].

During a study, four instrumentation methods were used, divided into groups: SSK, SAF, PNT, and REC, but the most efficient was SSK, used as a more standard method of root canal treatment in C[36]. SSK—The preparation technique consisted of a circumferential throw for curved and narrow regions that showed resistance during this movement, integrated with gentle rotation combined with subtle traction[36].

Irrigation

Endodontic irrigation consists of cycles of 2.5% sodium hypochlorite (NaOCl) and 17% trisodium EDTA[37]. Sodium hypochlorite is the most widely used endodontic irrigant due to its ability to dissolve organic tissue. It has been proven that the higher the concentration of this solution, the better its cleaning ability[38].

During irrigation, the use of auxiliary devices such as Easy Clean (Easy) is recommended, which has a distinctive active part similar to an "airplane wing." The performance of this rotary device (size 25.04) appeared to be effective in cleaning curved mesial root canals of lower molars[36]. Another auxiliary method for irrigation is Passive Ultrasonic Irrigation (PUI) to increase the capacity for irrigation and debris removal in root canals. Once in contact with the irrigating solution in the canal, the insert is connected to the ultrasound unit, which produces cavitation and acoustic waves. These findings improve the penetration of the solution; thus, chemical cleaning is enhanced, particularly in areas of complicated anatomy.

Intracanal Medication

Calcium hydroxide intracanal medication is widely used and especially indicated for canals with varied anatomies, but the paste must be in contact with the canal walls for the introduction of OHy ions and Ca2+ ions. The treatment phase includes the placement of calcium hydroxide as an intracanal dressing, which remains in the canal for 14 days. This material is known for its antimicrobial properties, as well as for its role in tissue repair[36].

One study used UltraCal XS paste (Ca $(OH)_2$) with two different application techniques[35]. In the first technique, UltraCalXS material was placed using a syringe connected to a 29-G NaviTip needle. The needle was placed 2 mm from the end of the canal, and after applying the paste, the syringe was removed. Next, a cotton ball was placed over the canal opening and sealed with Caviton. In the second technique, known as the Navitip needle syringe technique followed by a lentulo spiral, immediately after an injection of CA(OH2), a 25 mm lentulo spiral was placed in the canal 1 mm from the working end. The instrument was activated at low speed (300 rpm) in a clockwise direction to better distribute the material. Then, the spiral was removed, and the syringe was used again to add more paste until reflux, and finally, a cotton ball was placed over the canal opening and sealed with Caviton. After analyzing the samples in micro-CT, it was observed that the technique associated with the use of the lentulo spiral showed greater effectiveness in distributing the calcium hydroxide paste within the root canal[40].

Filling

Lateral condensation using gutta-percha cones and calcium hydroxide-based endodontic cement after the dressing has taken effect is recommended for filling the canal[40]. According to Walid *et al*. (2018) [41], for a "C"-shaped canal, it is suggested to place two gutta-percha cones, one in the distal part and the other in the mesial part[31].

Two different protocols were used for filling root canals with a C-shaped anatomy. The first consisted of combining lateral and vertical condensation techniques, using gutta-percha cones and endodontic cement (AH Plus). Initially, a master cone was positioned in the central region of the canal, followed by filling with accessory cones and thermal sectioning. The second protocol, after clinical alteration, used mineral trioxide aggregate (MTA) in the apical portion, which was condensed with the aid of ultrasound, providing better adaptation to the canal[42].

4. DISCUSSION

The results of this literature review indicate that C-shaped canals occur in various population groups, but with a higher prevalence in lower molars. This finding is consistent with the studies by Cook and Cox *et al.* (1979)[4], who described the main characteristic of this configuration: the fusion of two or more canals, forming a continuous isthmus, which is a striking peculiarity of this region. Similarly, Singh *et al.* (2022)[8] report a higher frequency of these canals in the Asian population, suggesting that genetic factors may influence their occurrence[8].

Research conducted by Melton, Krell, and Fuller *et al*. (1991)[5] demonstrated that the "C" configuration may present morphological variations along its length, influencing both the shape and number of root canals. These findings were corroborated by Fan *et al*. (2004)[28], who pointed out that the morphology of the crown or the shape of the canal orifice are not predictive of the actual configuration of the root canal system. These authors even propose a classification for the canals, categorizing them into types I, II, III, IV, and V.

With advances in technology, the diagnosis and analysis of these channels have become more accurate. Currently, it is possible to use radiographs and, especially, computed tomography to obtain detailed images of the internal anatomy [32]. Gao *et al*. (2019) [5], for example, presented images illustrating the different types of "C" canals, facilitating the visualization of their complexity.

The chemical-mechanical preparation of "C"-shaped canals is a notable challenge, and there are few studies that report the correct way to perform the treatment. It is essential to exercise caution when using instruments, due to the risk of creating steps, perforations, and difficulties in narrow or isthmus-shaped canals[17]. For this reason, the use of rotary instruments is recommended, as they provide superior cleaning compared to manual instruments and offer greater apical control. A significant advantage is their ability to adapt to the complex morphology of these canals, which can result in fewer instrumentation errors[35].

5. CONCLUSION

Despite the positive results in the approach to "C" canals, there is a limitation in studies that delve into chemical-mechanical preparation and the best forms of treatment, which restricts the current findings. To improve understanding of the morphology and clinical challenges of C-shaped canals, future research with greater sample diversity and using advanced resources, such as computed microtomography, is essential.

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