EAS Journal of Dentistry and Oral Medicine
Abbreviated Key Title: EAS J Dent Oral Med
ISSN: 2663-1849 (Print) & ISSN: 2663-7324 (Online)
Published By East African Scholars Publisher, Kenya

OPEN ACCESS

Volume-6 | Issue-2 | Mar-Apr-2024 | DOI:10.36349/easjdom.2024.v06i02.003

Review Article

Importance of the Microstructure Network of the Tooth for Root Canal Treatment from a Pre-Grade Student Context: Literature Review

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Article History
Received: 14.02.2024
Accepted: 22.03.2024
Published: 27.04.2024

Journal homepage:
https://www.easpublisher.com

Quick Response Code

Abstract: Understanding the intricate anatomy of the pulp cavity and the root canal system of dental organs is of utmost importance for dental practitioners. This knowledge and other clinical and theoretical considerations contribute to a surgical process with an almost perfect success rate. This literature review was conducted with the primary goal of enhancing this understanding. A comprehensive search was performed across multiple research databases, including Google Scholar, PubMed, and Scielo. This search encompassed articles with no restrictions on publication date due to the importance of some postulates and laws. This comprehensive review delves into the dental organ's intricate morphology, clinical divisions, the definitions, fundamentals, and classifications that have garnered widespread acceptance within the scientific community. These include the laws articulated by Krasner and Rankow, which pertain to the pulp chamber. Also, we examine Vertucci's classification, which provides insights into the diverse configurations of root canals. Furthermore, we scrutinize the nomenclature of Pucci and Reig, which systematically categorizes variations in the root portion of a tooth. Moreover, we emphasize the critical relevance of this knowledge to clinical practice. Each aspect is not an isolated concept but an integral part of the puzzle when performing a root canal treatment. By comprehending these intricate details, clinicians can make informed decisions, plan procedures more effectively, and execute a precise and successful clinical approach.

Keywords: Pulp Anatomy, Morphology, Krasner and Rankow's Laws, Vertucci's Classification, Pucci and Reig's Nomenclature.

INTRODUCTION

Endodontics as a science is defined by the American Association of Endodontists (AAE) as "The branch of dentistry concerned with the morphology, physiology, and pathology of the human dental pulp and periradicular tissues. Its study and practice encompass the basic and clinical sciences, including the biology of the normal pulp and the etiology, diagnosis, prevention, and treatment of diseases and injuries of the pulp and associated periradicular conditions" [1].

Root canal treatment aims to clean and shape the pulp cavity and its roots, followed by their obturation with a biocompatible material [2].

Following these definitions, we can infer the importance of knowing the usual and healthy state of the pulp and the morphologic variants that it may present; ignoring these may condition the success of the treatment in the long term, which otherwise may be easily avoided [3].

Corroborating this declaration, we must remember Pathways of the Pulp from Cohen, *"A thorough knowledge of tooth morphology, careful interpretation of angled radiographs, and adequate access to and exploration of the tooth's interior are prerequisites for treatment."* [2].

Having established the importance of knowing the pulp anatomy, I will start by describing the main

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components of the pulp cavity: the pulp and the dentin; afterward, the pulp cavity will be described, as well as its anatomic and functional divisions: the pulp chamber and the root canals.

Pulp

The pulp was described by the AAE in 2020 as "A richly vascularized and innervated specialized connective tissue of ectomesenchymal origin; contained in the central space of a tooth, surrounded by the dentin, with inductive, formative, nutritive, sensory and protective functions [1].

Other authors integrate this definition by presenting the pulp as an amalgam of components of loose connective tissue, like collagenous, reticular, and elastic fibers, nervous fibers, abundant blood vessels, and intercellular substances [1].

Dentin

Likewise, the AAE described the dentin as "A mineralized tissue that forms the bulk of the crown and root of the tooth, giving the root its characteristic form; surrounds coronal and radicular pulp, forming the walls of the pulp chamber and root canals; composition is approximately 67 percent inorganic, 20 percent organic and 13 percent water." [1].

Dentin-Pulp Complex

Based on the descriptions given by the AAE about the pulp and the dentin, and due to the difference they possess in their cellular composition, we may incorrectly infer that both components don't have a close relationship, the dentin acting just as a barrier that protects the pulp; this conclusion cannot be further away from the truth, the reason is that the dentin and the pulp act in such an intimate way that it may be considered a functional and indistinguishable complex, thus receiving the dentin pulp complex [4].

Diverse clinical situations exist that confirm this relation of the functional unit that the pulp and the dentin share, such as the capacity of the pulp to create dentin in response to an external stimulus, the nervous sensibility that the pulp provides to the dentin, and the response of the pulp connective tissue to dentin damage, without having to be directly stimulated by the external force [4].

Pulp Cavity

Attributable to the opinion of different authors, we may define the pulp cavity as the space that is located in the interior of the crown and the root of the tooth; it contains the pulp connective tissue and is delimited by dentin, except at the level of the apical foramina, and follows the approximate shape of the tooth, it is divided into two portions: the pulp chamber, located inside the portion corresponding to the anatomic crown of the tooth, and the root canal, located inside the anatomical root [1, 2].

Pulp Chamber

The crown portion of the pulpal cavity is known as the pulp chamber [1], this contains the most significant concentration of pulp in a tooth; it follows the rough shape of the external portion of the crown, which is unique and generally large. Its shape is generally cuboid; it has a roof, a chamber floor, and four lateral surrounding walls: mesial, distal, buccal, and lingual or palatal [5].

The divisions inside the pulp chamber area [5]:

1. **The occlusal/incisal wall or roof:** It presents a concavity towards the occlusal face or the incisal edge, and it commonly has prominences directed towards the cusps of the pulp horns.
2. **The lateral surrounding walls:** As mentioned before, there are four of them, and each corresponds to a wall of the tooth's crown: mesial, distal, buccal, and lingual or palatal; they frequently present a spur that forms a step in the deepest region of the wall.
3. **The cervical wall or floor:** Is "the opposite side of the roof and more or less parallel to the occlusal wall”. In the cross-section of the tooth, at the height of the Cement Enamel Junction (CEJ), it frequently shows a convex and smooth surface in the middle part, with conical niches in the angles of it, corresponding to the entry orifices of the root canals.

In the roof of the pulp chamber, the pulp horns can be observed; they are pulp protuberances that extend in the direction of the tooth's cusps. Due to age and as a result of masticatory trauma, these pulp horns may decrease in size to the extent of being almost entirely replaced by secondary dentin. During access cavity preparation, the operator would feel the dropping effect of the bur earlier on in a younger tooth as opposed to an older tooth, due to the effects of diverse types of trauma not having as much impact on the pulp chamber [6].

The cervical wall or floor is by far the most studied portion of the pulp chamber, and with fair reason, due to its clinical importance at the time of a root canal treatment, given that it presents the entry orifices of the root canal system itself.

Supporting the statement is the clinical study made by Krasner and Rankow. As a result, two categories of anatomic patterns were described: the relationship of the pulp chamber to the clinical crown and the relationship of orifices on the pulp chamber floor [7].

Relationships of the Pulp Chamber to the Clinical Crown

Through the application of a study made by Krasner and Rankow(2003), in which 500 teeth (distributed equally and with different crown conditions) were examined, two sets of rules were made, the first one regarding the relationships of the pulp chamber to the clinical crown and the second one regarding reference points of the pulp chamber floor [7].

Law of Centrality: *The floor of the pulp chamber is always located in the center of the tooth at the level of the CEJ (7).*

This law may be used as a guide when accessing the cavity. However, it must be noted that this law only applies at the CEJ level and does not consider if the tooth is heavily restored with a crown more prominent than the original or other factors that may modify the occlusal portion [8].

Law of Concentricity: *"The walls of the pulp chamber are always concentric to the external surface of the tooth at the level of the CEJ"* [7].

This law may help the dentist in the task of extending access to the cavity efficiently. If protuberances of the CEJ were to exist in a specific direction, the pulp chamber also extends in that direction [8].

Law of the CEJ: *"The CEJ is the most consistent, repeatable landmark for locating the position of the pulp chamber."* [7].

This law, paired with the proposals mentioned above, makes it clear that our foremost priority while performing a root canal treatment is locating the CEJ, given that all the laws orbit toward its location.

After locating the pulp chamber on our tooth, the following step represents great importance in the scheme of a root canal treatment: finding the location of the root canals themselves. To aid in this endeavor, the authors Krasner and Rankow proposed another set of rules regarding the entry to the space that belongs to the radicular pulp, the floor of the pulp chamber.

Importance of the Pulp Chamber Floor

From a clinical point of view, the floor is the section where the largest concentration of pulp and dentin ends. The root canal begins, in single-rooted teeth, it can be viewed as the place where the pulp chamber becomes considerably narrower, and the radicular portion of the pulp-dentin complex begins; quite differently, in multirooted teeth, the floor is viewed as the part where the pulp chamber bifurcates or trifurcates, depending on the number of roots, and various foramina corresponding to different root canals can be observed.

In multirooted teeth, there is another anatomical landmark that can be appreciated and holds particular clinical relevance: the rostrum canallium; it is a convex zone in the floor of the pulp chamber, in which the demarcation lines that interlock the opening foramina to the root canals begin.

We must understand the importance of the rostrum canallium while performing a root canal treatment since it does not just mark the cross between the entry of the root canals but also the limit where we should perform our cavity; the motive is that below this anatomical landmark lies the furcation, in consequence, a dentist without the adequate experience may commit an iatrogenesis when trying to remove decayed tissue from a cavity or while trying to create an access to a calcified canal orifice, resulting in a perforation.

A feature that may be found in multirooted teeth is a variation in the disposition of the root canals; where one or more accessory root canals can start at the bifurcation or trifurcation of the dental organ and terminate in the interradicular region of teeth, these are known as Furcation canals [9].

Relationships on the Pulp-chamber Floor

The following laws were coined in an attempt to find patterns and reliable reference points to locate the entry of the root canal system.

"Law of Symmetry 1:

Except for maxillary molars, the orifices of the canals are equidistant from a line drawn in a mesial-distal direction through the pulp-chamber floor". [7].

"Law of Symmetry 2:

Except for the maxillary molars, the orifices of the canals lie on a line perpendicular to a line drawn in a mesial-distal direction across the center of the pulp chamber floor" [7].

The laws of symmetry are invaluable tools used to determine the position of the canals, and it is these same laws that can help find an unexpected additional canal, as well as reveal if the access and cleaning off the chamber floor was done in an adequate manner [7].

"Law of Color Change: *the color of the pulp-chamber floor is always darker than the walls".* [7].

This law offers the operator a guide to determine if the pulp chamber floor has been correctly cleared; if the junction between the chamber floor and the walls 360 degrees around can be outlined, the access has been completed correctly [8].

"Law of Orifice Location 1: *the orifices of the root canals are always located at the junction of the walls and the floor"* [7].

"Law of Orifice Location 2: *the orifices of the root canals are located at the angles in the floor-wall junction"* [7].

"Law of Orifice Location 3: *The orifices of the root canals are located at the end of the fusion lines of root development."* [7].

All the laws mentioned above have been repeatedly confirmed over time, and they have withstood the constant updates of other rules and principles once thought to be set in stone in the field of dentistry. An independent study was conducted years later to prove this set of laws, and through more methods, the same conclusions were reached [10].

Clinically, there are many diagnostic measures for locating the entry orifices, such as preoperative X-rays, cone-beam computed tomography, the use of apex locators, ultrasonic tips to clean the surface of materials obstructing access to the orifices, staining the chamber floor with 1% methylene blue dye [8], as well as performing the sodium hypochlorite "champagne bubbles" test and locating points where blood is observed, which can help us locate entry foramina to new canals [11].

Root Canal

According to Cohen's "Pathways of the pulp", *"A root canal begins as a funnel-shaped canal orifice, generally at or just apical to the cervical line, and ends at the apical foramen, which opens onto the root surface at or within 3 mm from the center of the root apex"* [2].

The root canal system houses two canals or portions within it that the clinician must thoroughly understand to provide proper endodontic therapy; the dentinal canal, which houses the root pulp, is the area of operation of the endodontist, while the endodontist must respect the cemental canal to avoid causing pathological issues in the periapical region of the tooth [12].

Both the dentin and the cement portions unite near the anatomical root; this landmark is defined as the CDJ (Cementodentinal junction); the AAE describes it as "The region at which the dentin and cementum are united; commonly used to denote the point at which the cemental surface terminates at or near the apex of a tooth; the position can range from 0.5 to 3.0 mm from the anatomic apex" [1]. Most root canals do not follow a straight line but rather deviate in a buccolingual direction, which can cause problems when shaping and cleaning the canal [2].

The root canal system can be divided into three sections, starting from the lowest portion of the chamber floor to the end of the root [1].

- Cervical third
- Middle third
- Apical third

Canal Classifications

Different nomenclatures have emerged in an attempt to arrange the many accessory canals that exist; The Pucci and Reig Nomenclature (1944) was created to name the different types of canals that can exist in a tooth, to most accurately describe the trajectory that a root follows, and how it relates to the different canals that may exist in just one root. The importance of this classification lies in the truth it speaks, we must not see the canal system as a singular lane or just a lane with a few deviations, rather we must see it as a microvascular and complex system within the tooth; in a normal endodontic treatment in which the objective is to remove the dental pulp or the remains of it, just a file will not be enough to reach all the multiples ramifications of the canal due to its microscopic size, that's when intracanal irrigation with the capability to dissolve organic matter is needed [13].

Main Canal: It is the most essential canal that runs along the dental axis, reaching the root apex without interruptions.

Collateral Canal

This canal runs more or less parallel to the main canal, potentially reaching the periapical region independently, with a smaller caliber than the main canal.

Intercurrent or Intercanalicular Canal

It is a small canal that connects two or more canals, maintaining its relationship with the dentin without reaching the cementum or periodontium.

Recurrent Canal

It is a canal that, originating from the main canal, follows a dentin path to rejoin the same canal but always before reaching the apex.

Lateral Canal: It runs from the main canal to the lateral periodontium, generally above the apical third.

Secondary Canal: It branches off from the main canal at the level of the apical third and directly reaches the periapical region.

Accessory Canal: It is a canal that branches off from a secondary canal to terminate on the external surface of the apical cementum.

Apical Delta:

These are multiple terminations found near the root apex, branching off from the main canal to end in small finger-like extensions in the apical area. It gives an origin to multiple openings instead of a single main foramen.

Interradicular or Furcation Canal:

It originates from the floor of the pulp chamber and terminates in the furcation area, exclusive to multi-rooted teeth [14].

The AAE has proposed a different approach based on other methods, such as Micro-computed tomographic which includes five different types [15], this classification synthesized the one given by Pucci and

Reig and also added two additional canal configurations that had not been properly addressed beforehand [1].

*"**Accessory Canal:** Any branch of the main pulp canal or chamber that communicates with the external surface of the root."*

*"**Blunderbuss Canal:** Term denoting an incompletely formed root in which the apical diameter of the pulp canal is greater than the coronal diameter."*

*"**C-shaped Canal:***

A pulp canal anatomy having the cross-sectional shape of the letter "C"; found in mandibular second molar teeth in which mesiobuccal and distal canals communicate due to fusion of the mesial and distal roots."

*"**Furcation Canal** — An accessory canal located in the furcation."*

*"**Lateral Canal** — An accessory canal located in the coronal or middle third of the root, usually extending horizontally from the main canal space."*

Due to the variety of canals an operator may encounter, several authors have attempted to create systems to classify the different configurations of root canals in dental organs.

In particular, a certain study conducted in 1984 by Vertucci, in which he cleared and stained the root canals of 2400 teeth, offered eight distinct configurations (Fig. 1), ranging from the simplest representing anterior teeth with a single canal that extends from the pulp chamber to the apex, to those that present three canals throughout the entire root canal pathway [17].

Vertucci's Classification of Root Canal Systems (1984)

Type I: A single canal extends from the pulp chamber to the apex [1].

Type II: Two separate canals leave the pulp chamber and join near the apex to form one canal [2-1].

Type III: One canal exits the pulp chamber, divides into two in the root, and then fuses back together before exiting as one [1-2-1].

Type IV: Two separate and distinct canals extend from the pulp chamber to the apex [2].

Type V: One canal exits the pulp chamber and divides near the apex into two distinct canals with separate apical foramina [1-2].

Type VI: Two separate canals exit the pulp chamber, merge in the body of the root, and then divide again near the apex to exit as two distinct canals [2-1-2].

Type VII: One canal exits the pulp chamber, divides, then rejoins in the body of the root, and finally divides again into two distinct canals near the apex [1-2-1-2].

Type VIII: Three distinct and separate canals extend from the pulp chamber to the apex [3].

The creation of this classification proposed a solution to a problem that had not been systematically explored before, as having a preconceived idea of the variations that can be found in a root canal system allows the clinician to make informed planning decisions, dictate the location of the access point, and provides a rational approach to any issues that may arise during treatment [16].

Currently, more variations than those proposed by Vertucci have been discovered. An example of this can be found in a study published about the Turkish population, which identified 14 additional variations beyond the original classification [17].

The study conducted by Sert and Bayirli, among others, has demonstrated the need for dentists to consider the variations that can exist among the same dental pieces from patient to patient. Factors such as the patient's race and gender should be taken into account in procedure planning [17-19].

All of this data makes it clear that clinicians are faced with very complex and variable root canal systems on a daily basis. They must use all available resources to achieve good results [2].

Apical Third of the Root Canal System

Concluding with the pulp anatomy, what can be considered the entry point of the tooth will be described, as it is through this section that the neurovascular component of the tooth enters. According to Cohen, the apical region of the root presents three anatomical and histological landmarks: the apical constriction, the cementodentinal junction, and the apical foramen [2].

According to Kuttler (1955), the apical constriction is located 0.5 to 1.5 mm from the apical foramen, depending on the age and intrinsic variations of each tooth [20].

The AAE defines the cementodentinal junction as "The region where dentin and cementum are joined; commonly used to denote the point where the cemental surface terminates at or near the apex of a tooth; a position that ranges from 0.5 to 3.0 mm from the anatomical apex" [1].

The apical foramen is a funnel-shaped rounded border, which serves to mark the termination of the cemental canal and the external surface of the root [20].

We must remember the importance of each portion of the root's apical third; ignoring their existence or failing to locate or consider them during the cleaning and shaping of a canal can lead to over or under-instrumentation, or overfilling, which in turn can cause pulp and/or periapical pathology not only in the tooth but also in the surrounding area near that apex.

With this in mind, most clinicians and authors recommend that the canal shaping must not end at the apical constriction, as it can often be a purely theoretical reference point.

The recommended termination points are as follows [2]:

- 1 mm from the apex when there is no root reabsorption.
- 1.5 mm from the apex when only root reabsorption has occurred.
- 2 mm from the apex when both root and bone reabsorption are present.

CONCLUSION

A root canal treatment may be considered a difficult endeavor by an inexperienced clinician. Moreover for a beginner student in endodontic therapy, since most of the treatment is done without directly looking at a part of the area you are working with, but with the right tools such as good lighting, rubber dam isolation, proper image, and most importantly, adequate knowledge of the anatomical structures of the tooth; the anxiety behind the treatment can be reduced. The laws and postulates mentioned in the review are to be considered the minimum needed to achieve this task, these laws are to be remembered in all our endodontic treatments and also serve as a good base for developing further knowledge in this area.

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Cite This Article: Salcido-Navarro Francisco Javier, Salcido-Navarro Natalia Marina, Saavedra-Martinez Claudia Lisette, Fuchen-Ramos Dulce Martha (2024). Importance of the Microstructure Network of the Tooth for Root Canal Treatment from a Pre-Grade Student Context: Literature Review. *EAS J Dent Oral Med, 6*(2), 16-21.