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Review Article

Complexity and Variability of the Endodontic System - Evolution of Root Canal Morphology Classification Systems

Bogdan Dimitriu[1]*, Ana-Maria Țâncu[2], Cristina Nistor[1] and Oana Amza[1]

[1]Department of Endodontics, "Carol Davila" University of Medicine and Pharmacy Bucharest, Romania

[2]Department of Complete Denture, Faculty of Dental Medicine, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania

***Corresponding Author:** Ana Maria Tancu and Cristina Nistor, Department of Complete Denture, Faculty of Dental Medicine, "Carol Davila" University of Medicine and Pharmacy and Department of Endodontics, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania.

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Abstract

As stated by The American Association of Endodontists [1], the primary objective of endodontic treatment is to prevent and intercept pulpal/periradicular pathosis and to preserve the natural dentition when affected by pathosis. To achieve this goal, a thorough knowledge of the endodontic system is to be considered. This also implies having the best possible means to classify and communicate the intricate root canal morphology, in term of number of roots, root canals, root canal orifices and apical foramens.

Keywords: Endodontic System; Classification

The purpose of the endodontic treatment is to keep and reintegrate the nonvital tooth in the dental system, aiming to eliminate root canal microbiota, prevent or treat periapical lesions and restore the tooth.

The diagnosis, based on clinical and paraclinical examination, allows the application of the clinical procedures that comprise the treatment stages, represented by:

- Creating the access cavity;
- Removing the contents of the whole endodontic system;
- Negotiation of root canals and determination of working length;
- Shaping: getting shape by preparing root canals;
- Cleaning: removing all the pathological factors existing in the endodontic system;
- Filling the root canals;
- Restoring the tooth.

Shaping and cleaning, as procedures involved in the chemo-mechanical approach, are paramount in the economy of the whole endodontic treatment. The solid knowledge of root internal morphology is, from this perspective, an essential condition. This involves the identification of all the root canals, their place and trajectory from the root canal orifices to the apical constriction, highlighting the elements of anatomic detail present along them and the interrelationships existing between the root canals comprised into the same root.

The root canals are not simply conical spaces. On the contrary, there are significant anatomical complexities and an extremely variability [2].

On the one hand, morphology of root canal cross-sections varies along its length, rarely being of a round shape. Root canals are frequently asymmetric, irregular shaped, with lateral fins, isthmuses partially connecting two different canals, bifurcations, lateral canals, etc.

On the other hand, the root canal length is different from that of the corresponding root; the apical constriction - the cemento-dentinal junction, and also the limit of the endodontic instrumentation - is very rarely exactly located at the level of the anatomic or radiographic apex, respectively.

The root canals also show a high variability, both highlighted by their number and by the different morphological characteristics specific to each individual tooth.

Understanding the complexity of the endodontic system is essential to accurately apply the principles underpinning its shaping and cleaning.

These aspects have been known and illustrated even since the 19th century: Georg Carabelli (1842), E. Mühlreiter (1870), Greene Vardiman Black (1890), and Alfred Gysi (1892) presented the anatomical specificities of the endodontic system [3-6].

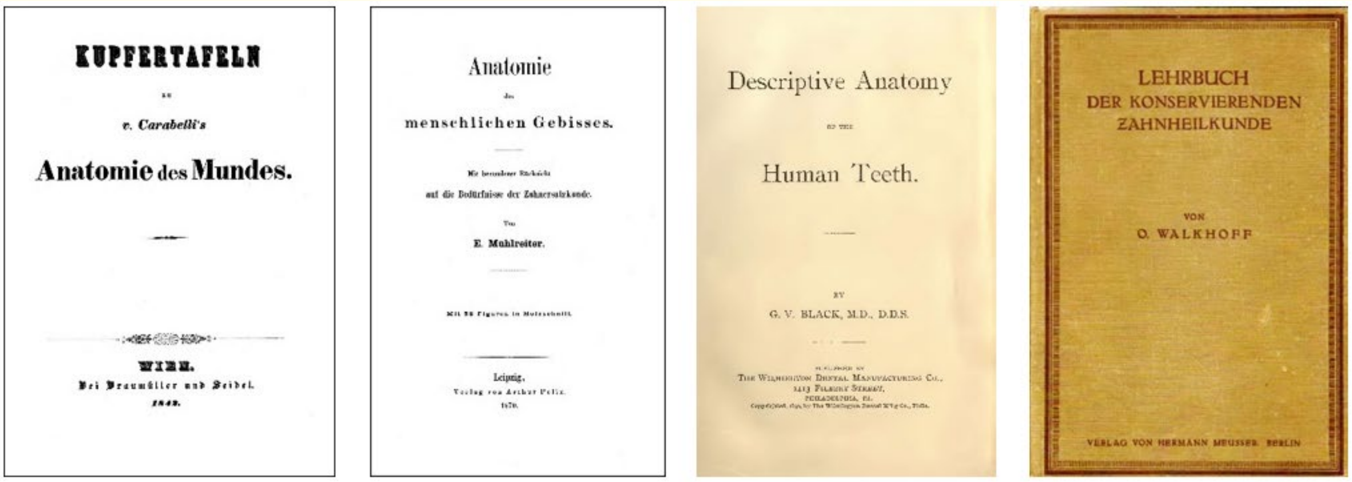

Figure 1: Works published by Carabelli, Mühlreiter, Black and Walkhoff.

In 1921, Walter Hess and Otto Walkhoff published extremely accurate images of the root canals, demonstrating the existence of a true endodontic system [7].

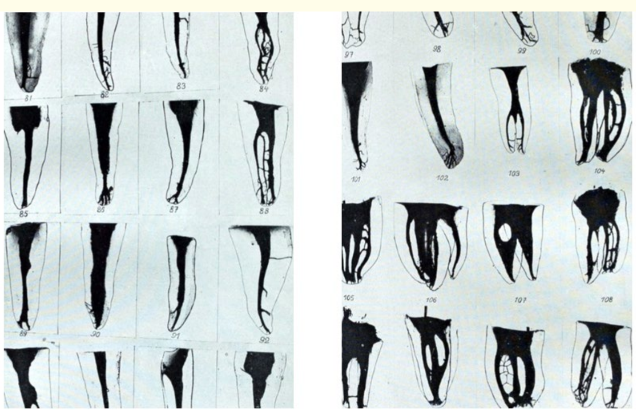

Figure 2: Images of the endodontic system created by Hess and Walkhoff (1921).

This prompted the need to use classification criteria which could deal with the completely different clinical situations encountered during the endodontic treatment.

Therefore, several systems for root canal classification were introduced, among the first being the one imagined in 1969 by Franklin Weine, which included three types, completed in 1982 with a fourth one (types I - IV) [8].

Frank Vertucci depicted in 1984 a root canal classification system comprising eight types (I - VIII), very commonly used up to the present day [9,10].

Figure 3: The Franklin Weine classification system.

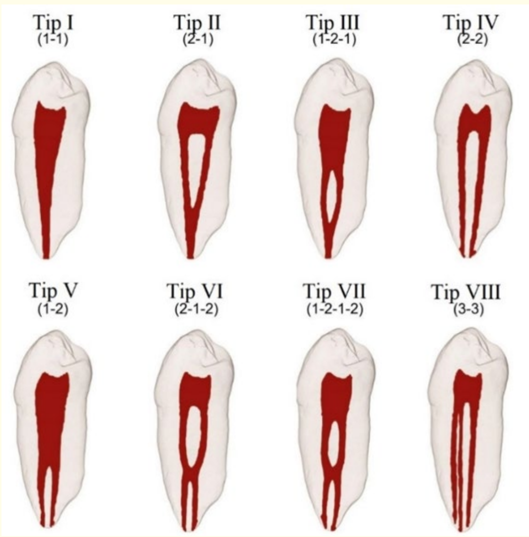

Figure 4: The Frank Vertucci classification system.

Kishor Gulabivala added in 2001 more configurations to the Vertucci system [11,12].

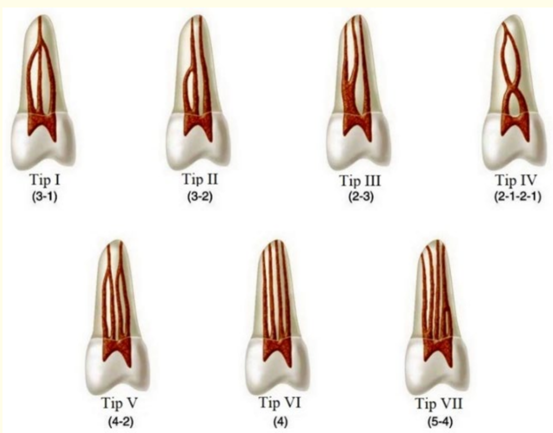

Figure 5: The Kishor Gulabivala classification system.

Despite the great number of existing classification systems, the diversity of endodontic morphological configurations makes it always possible to add new types that have been identified at different population groups. Versiani and Ordinola-Zapata have identified 37 different types of endodontic configurations [13].

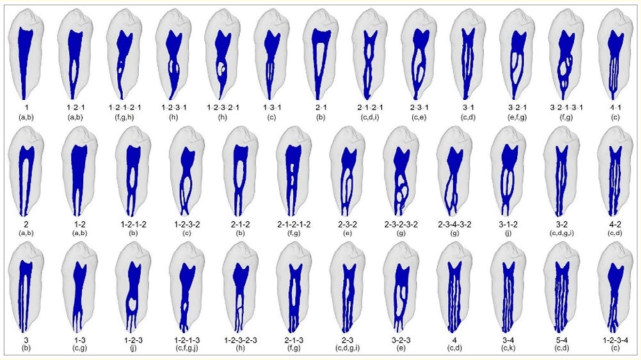

Figure 6: The 37 types of endodontic configurations identified in the study published by Versiani and Ordinola-Zapata.

Studying and highlighting the endodontic system of extracted teeth was initially performed by injecting dyes into pulp chambers and root canals, followed by axial sectioning of the roots. Obtaining a fair image was obviously conditioned by the fluidity and volatility of the dye being used [3-7].

Current systems are based on the use of clearing methods, CBCT and micro-CT investigations: Gulabivala [11,12], Versiani [13], Sert and Bayirli (types IX - XXIII) [14], Ahmed., *et al*. [15].

Studies aimed at comparing the accuracy of the various methods of highlighting the configuration of endodontic systems demonstrate the difficulty of using a single method. Especially in the case of roots having multiple root canals, there are significant discrepancies between the results of different investigations, which also leads to different statistical considerations between the studies [16].

These are the basic reasons for the most recent proposals for new endodontic classification systems, published and authored by some of the well-known personalities in the world of endodontics, with important studies concerning systematization and classification of root canals [15].

This new approach introduces an accurate, simple, and reliable system adaptable to any endodontic configuration. Such a system should also allow a classification of root canals based on information obtained by any of the investigative methods currently used.

The system proposed by Ahmed, Versiani, De-Deus and Dummer [15] is based on codes regarding three anatomical components:

- Tooth number TN;
- Number of roots R;
- Configuration of root canals OCF: the route of the root canal is followed from the root canal orifice O, along the length of the entire canal C, to the apical foramen F.

According to this system, for single-rooted teeth the notation is of the type:

$^{R}TN^{O\text{-}C\text{-}F}$

Therefore, for the first maxillary left premolar (TN = 24) having one root (R = 1), two root canals (two root canal orifices O = 2) and two apical foramens (F = 2) its notation is as follows:

$^{1}24^{2\text{-}2}$

For multi-rooted teeth the separate configuration of each root is considered:

- For two roots: $^{2}TN\ R1^{O\text{-}C\text{-}F}\ R2^{O\text{-}C\text{-}F}$
- For three roots: $^{2}TN\ R1^{O\text{-}C\text{-}F}\ R2^{O\text{-}C\text{-}F}\ R3^{\ O\text{-}C\text{-}F}$

Therefore, for the second right mandibular molar (TN = 47) with two roots (R = 2), a distal canal with one root canal orifice (O = 1) and one apical foramen (F = 1) and respectively 2 distinct mesial canals (C = 2), respectively, with two root canal orifices (O = 2) and two apical foramina (F = 2), its notation is represented by:

$^{2}47\ D^{1}\ M^{2}$

It is worth noting that the system implies that when the number of root canal orifices, root canals and apical foramens existing in the same root is identical, then O = C = F and therefore in the example above O = C = F = 2, and figure 2 is noted just once. If the two mesial canals would have had an isthmus and therefore would have been a merger of the two canals on a certain length, then O = 2, C = 1 and F = 2, and the notation for tooth 47 would have been the following:

$^{2}47\ D^{1}\ M^{2\text{-}1\text{-}2}$

For the left maxillary three-rooted first molar, with one distal canal, one palatal canal and two distinct mesiobuccal canals, MB1 and MB2 respectively, merging into one single apical foramen, the notation is:

$^{3}26\ MB^{2\text{-}1\text{-}1}\ DB^{1}\ P^{1}$

Where MB is the mesiobuccal root, DB is the distobuccal root, and P is the palatal root.

This system aims to provide detailed information concerning external and internal root anatomy, without considering minor morphology elements or being determined by developmental abnormalities. It thus allows a simple and universally valid classification, with chances of being generally accepted in endodontics.

Taking into consideration the afore mentioned, it can be stated that the evolution of the classification systems comes to join the state-of-the-art technology used in endodontic diagnosis and treatment. The present possibilities offered by digital imaging, including Conical Beam Computer Tomography (CBCT), micro CT, as well as the clinical means of illumination and magnification provided by the operating microscope, allow nearly ideal conditions for diagnosis and endodontic treatment.

It is however obvious that the extreme complexity and variability of the endodontic system make each case a unique one, and often a real challenge for even the most skilled endodontist.

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