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Original Article

Proposal for a simple and effective diagrammatic representation of root canal configuration for better communication amongst oral radiologists and clinicians

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ABSTRACT

Objectives: Root canal anatomy has been proved to be a complex canal configuration system. The negotiation and cleaning of this system is essential for successful root canal treatment. The present root canal classification systems are unable to transfer the clinically relevant information about the canal system from the oral radiologist to the treating clinician. Thus, a simple and effective diagrammatic representation of the canal system, depicting the major canals, important changes during their course along with other relevant information has been presented.

Methods: The proposed representation consists of five horizontal lines dividing the tooth into four segments from the point of reference to apical foramen. Each line has been designated with different line style. The diagrammatic images, one anterior and one posterior multi-rooted tooth, are given for easy understanding of the orientation of image. The whole image can be saved in portable network graphics format and can be imported to any word processing document. The image can be printed in the reporting sheet.

Result: Applying the same proposal, some of the diagrammatic representations have been showed.

Conclusion: This proposal for diagrammatic representation of root canal configuration can be helpful in getting an approximate distribution of the canals in a relatively simple manner. This scheme also provides valuable clinical information about the root canal system, which the other classifications fail to represent.

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1. Introduction

Knowledge of the root canal anatomy plays an important part for the successful treatment of the tooth and the patient as whole. The presence of an untreated missed main canal, lateral canal or even an isthmus may be a reason for failure. It is extremely important for the clinician to treat the entire root canal system. A number of classifications have been given by various authors^{1–3} to represent the root canal system. Amongst these, Weine's Root canal classification is one of the easiest and simplest one, which classifies the root canal system of a root into four types: Type 1 – one canal from pulp chamber to apex; Type 2 – two canals from pulp chamber but merging short of apex; Type 3 – two canals from pulp chamber to apex; and Type 4 – one canal from pulp chamber but dividing into two before apex.

Refinements in tooth clearing procedures have led to better understanding of root canal anatomy. Further with the availability of newer techniques like micro-Computed Tomography and Cone-Beam Computed Tomography (CBCT), an accurate and rapid representation of root canal anatomy of the concerned tooth is possible. These advanced diagnostic techniques are able to recognize various variations as isthmuses, second mesiobuccal in maxillary molars,^{4,5} middle mesial in mandibular molars,^{6,7} etc. in the root canal morphology which were earlier concealed due to the limitations of our radiographic techniques. Although three-dimensional imaging represents advancement in the field of root canal treatment, it is still not favored as a routine first line imaging modality due to its radiation concerns, and its use is limited to cases suspected of having complex canal systems, or endodontic failures and mishaps.

The currently available classifications of the root canals are not able to depict the complexities of the canal system, which is essential during treatment. Although classifications^{8,9} have been proposed to accommodate the various intricacies of the canal morphology, these are difficult to remember and are with limited practical application.

Even when we are able to classify the imagined root canal system, transfer of required information to the treating clinician is limited and one is not able to communicate the approximate location of the changes using the present classification systems. Additionally, these classifications fail to represent the level or position of division or fusion of the canals. The facts gained by the radiologist during imaging should be reported in a manner keeping in mind that the ultimate usage of that information is documentation of the findings and treatment of the patient. This also emphasizes the importance of proper communication between radiologist and treating clinician. Knowing the root canal anatomy beforehand in turn will save the patient's chair side time and add to the clinician's confidence level resulting in improved quality of treatment.

Thus, there is a need for a representation, which reflects the major canals, isthmuses, and connections; and is simple to understand, draw, and communicate, to allow better communication between radiologist and treating clinician. This clinically oriented diagrammatic representation of the root canal anatomy presents the configuration of the root canal system in a simple comprehensible manner.

Aim and objectives of a simple diagrammatic root canal representation are as follows:

1. Should be simple to understand, draw, and communicate.
2. Represent the number of the canals.
3. Depict the location of the canals.
4. Represent the length of the canals.
5. Show the presence and location of the isthmuses and other ramifications.
6. Show confluences and bifurcations of the canals.
7. Able to include all the major root canal classification systems.
8. Able to represent most of the canal configuration.

2. Materials and method

The proposed representation (Fig. 1) consists of five horizontal lines, which divide the tooth into four segments. Coronapically, the first line, which is a dashed line and has "Ref." written at one end, signifies the point of reference from where the length of root canal is measured. The second one, a solid line marked as "Orf." at one end, depicts the orifice level or cemento-enamel junction (in case of single canal and taurodont teeth). The lowermost line, which is a solid one, represents the apical foramen of the root canal. The third and fourth lines (dotted lines) are the ones which divide the root canal into coronal, middle, and apical thirds; these regions are designated as C, M, and A, respectively. The diagrammatic images of teeth (one anterior/posterior single rooted and one posterior multi-rooted) are given for easy understanding of the orientation of image. The whole image has a transparent background and is saved in portable network graphics (PNG) format. The image can be rotated by 180° to correspond to either mandibular or maxillary teeth. It can be imported to any word processing document and a print of the image can be obtained in the reporting sheet.

2.1. Rules for drawing diagrammatic root canal representations

Freehand vertical lines should be drawn from top dashed line to the bottom solid line to represent the major root canals present in the tooth.

The lines representing the respective canals should be labeled at the start of the vertical lines.

The length of the individual canal from the point of reference to the apical foramen can be written (in millimeters), depending on the situation, either adjacent to the origin of its

Fig. 1 – The proposed diagrammatic representation image.

corresponding line, near “Ref.” line, or at the end, adjacent to the fifth line representing the apical foramen.

Intercommunications and isthmuses between the canals should be drawn keeping in mind the approximate level (coronal, middle, apical) of communication.

Fusion between canals can be shown by one vertical line merging into another or both the line joining together at the corresponding level.

Bifurcation in the canal should be represented by division of the line at the corresponding third. The orientation of the resulting canals can be labeled in the area adjacent to the fifth line. In addition to this, the diameter of the canals can be represented by the relative thickness of the lines representing the resultant canals.

Lateral and accessory canals, if identified, can be shown as blind lines originating from the main vertical line and running in horizontal direction at the corresponding locations.

If the major canals, instead of appearing at the pulpal floor as separate orifice, continue as single large canal and separate below the orifice, then the same can be represented as a thick band in the diagrammatic representation. The lines representing the divided canals, in such cases, can be labeled near the fifth line.

If the major canals, instead of appearing at the apex in separate apical foramina, join and continue as single large canal, then the same can be represented as a thick band in the diagrammatic representation starting from the corresponding third.

The above-mentioned rules can be simply summarized as “you draw what you see”.

2.2. Limitations of the present representation

The above-presented representation has limitations, which are inherent in two-dimensional representation of a three-dimensional network. It is not able to present either the exact location of the canal orifices or the location and orientation of the canals. The lengths of the canals are out of proportion in order to simplify the procedure of drawing and segmenting the canals.

3. Results

Applying the above-mentioned rules, some of the diagrammatic representations of the canals are given in the figures, which have used the PNG image mentioned in Section 2. Fig. 1 shows the image without any freehand drawing over it and Fig. 2 shows some variations in root canal anatomy as depicted in the diagrammatic representation. CBCT images and corresponding diagrammatic representations in two cases have been shown in Fig. 3 and another case in Fig. 4.

4. Discussion

Knowledge of root canal anatomy is a necessary prerequisite for any treating clinician and failure to negotiate and clean the canal system is one of the major reasons for unsuccessful root canal treatment. Complexities of the root canal system cannot

be overstressed and the present classification schemes fail to represent the same. Communication between the oral radiologist and treating clinician using the available classification schemes gives us a highly compromised understanding of the root canal system. Even in simple canal system such as “Type IV” of Weine,¹ one fails to communicate the location of bifurcation in the canal and whether the resultant canals are in buccolingual or mesiodistal orientation to each other. It also fails to inform whether the resultant canals were formed by simple division into two equal canals or one canal just sprouted out of the main canal. The above diagrammatic representation nicely covers the above-mentioned issues (Fig. 2a and d). The main intention of this proposal is not to complicate the representation but to simplify it, as it is based on the principle of “you draw what you see”.

The vertical lines representing root canals has been individually labeled at the first horizontal line itself for easier identification. Additionally, the resulting canals after division have been labeled adjacent to the fifth line to help in determining the orientation of the canals after division.

Length of the individual root canal has been mentioned either at the “Ref.” line or at fifth line representing apical foramina. An additional representation of canal length from orifice to the apical foramen can be done because many times the patient is referred for imaging before an access preparation has been made or the access preparation usually needs modification subsequently during treatment. Any such change in the morphology of the tooth will lead to changes in the root canal length. During such modifications, the length of the canal from the orifice might be useful in re-calculating the root canal length.

The segment of vertical lines between the “Ref.” line and “Orf.” line can be a solid, dashed, and dotted line or be altogether absent, in order to make the representation less crowded, but such an alteration should not lead to confusion or mis-representation of information.

When a root canal divides into two or more canals, writing the length of the resulting canals at the “Ref.” or “Orf.” line might lead to crowding and mis-interpretations. In such cases, a representation of the length of resultant canals, from the reference point to the apical foramen, can be written adjacent to the fifth line and is more meaningful and clinically relevant. When depicting the length in such a fashion, one should clearly specify whether the lengths are from “Ref.” or “Orf.” line either by writing “R” or “O” before each measurement or by giving a collective representation by writing “R” or “O” after the fifth line below the root apex of the diagrammatic tooth.

The measurement of root canal length using CBCT has been proven to be more accurate than the two-dimensional radiographic length measurements¹⁰ and have been considered to be close to actual endodontic working length,¹¹ but it should be kept in mind that such a representation of root canal lengths is only an approximation assisting the treating clinician in easily negotiating the canals, and should be confirmed by the use of apex locators.^{12,13}

Fusion or bifurcation of the canals is easily depicted in the diagrammatic representation as joining or dividing lines. The position at which it happens is shown in the corresponding third, which helps the clinician in determining the anticipated location of fusion or bifurcation (Fig. 2b). The thickness of the

Fig. 2 – Representation of some variations in root canal anatomy. (a) Representation of canal configuration of mandibular left molar (tooth number designated within the tooth diagram) with two roots (mesial and distal – represented as two solid bars below the fifth line). Distal root having two canals – distolingual and distobuccal (both 13 mm in length) meeting at the apical third. Mesial root having one canal which divides below the orifice (in the coronal third) into two canals – mesiolingual (length 14 mm) and mesiobuccal (length 13.5 mm) from the orifice (having an identifiable isthmus in the middle third). (b) Representation of canal configuration of mandibular right molar with three roots (Radix Entomolaris). Mesial root has three canals at the orifice with the middle mesial merging with mesiobuccal at approximately mid level. Distal root having a Wiene Type III configuration (with bifurcation immediately after orifice and joining few millimeters before apex). Distolingual root of 12 mm length is also represented. (c) Representation of canal configuration of mandibular left second premolar with a main canal having a thinner lingual offshoot at the junction of coronal and middle third. (d) Representation of canal configuration of maxillary left second molar having two roots (mesiobuccal and distopalatal). Mesiobuccal root having two canals (MB1 and MB2) with separate orifices, which merge at the mid level. Distopalatal root with two canals (DB and P) with separate orifices and merger in the apical third (having an identifiable isthmus in the middle third). (e) and (f) Both the diagrams representing maxillary right first premolar. (e) represents premolar with three roots (three solid bars above the fifth line representing P, MB and DB roots) with palatal canal dividing from the main canal trunk (see discussion regarding CEJ as “Orf.”) at the junction of coronal and middle third; mesiobuccal and distobuccal canals dividing at the mid level and continuing in their respective roots. (f) represents premolar with two roots (two solid bars above the fifth line representing P and B roots) with palatal canal dividing from the main canal trunk at the junction of coronal and middle third; mesiobuccal and distobuccal canals dividing at the mid level but present in the same root. (g) Representation of canal configuration of mandibular left second molar having a “C”-shaped configuration and two (M and D) roots. It has one mesial canal, which originates at the junction of coronal and middle third and continues in the mesial root; and two distal canals which have their separating approximately at the junction of middle and apical third. (h) Representation of canal configuration of mandibular right taurodont second molar having three roots (ML, Mb and D). The distal canal originates at the mid level and continues in the distal root, whereas the mesial canals are bifurcating at the junction of middle and apical third and continuing in their respective roots.

divided lines also gives the clinician an idea about the nature of the bifurcating canals. A bifurcated line, which is thinner and originating at a greater angle, signifies a smaller diameter canal, which originates as an offshoot of the main canal. Labeling the position of the divided lines near the fifth line

helps in determining the orientation of the resultant bifurcated canals and the initial precurved files can be placed accordingly which would result in easier and early negotiation of resultant divided canals. This is of great help in representing certain root canal systems like canines and mandibular

Fig. 3 – Showing the CBCT images and corresponding diagrammatic representations in two cases. (a) transverse section (TS) at cement–enamel junction (CEJ) of tooth 47; (b) buccolingual section showing relation between CEJ and pulpal floor; (c) TS at the level of bifurcation into distal and mesial canals; (d) TS at the level of bifurcation into mesiobuccal and mesiolingual canals; (e) TS at the level of fusion of distal and mesial canals; (f) mesiodistal (MD) section showing the relationship between distal and mesial canals; (g) diagrammatic representation of the case represented from (a) to (f); (h) Diagrammatic representation of the case represented from (i) to (r); TS of tooth 17 at CEJ (i), orifice of buccal and palatal canals (j), division of buccal canal into mesiobuccal and distobuccal canals (k), fusion of buccal canals (l); (n) to (q) shows the level to TS represented in buccolingual section; (m) buccolingual section showing the relation of buccal and palatal root; (r) mesiodistal section of the buccal root showing the bifurcation and confluence of buccal canals.

premolars, which many a time have an additional canal originating as a lingual offshoot of the main canal (Fig. 2c).

In cases where the pulp chamber is large and its division into canals occurs deep below the cement–enamel junction (CEJ), as in taurodonts (Fig. 2h) and teeth having “c” shaped canal system (Fig. 2g), the CEJ can be considered the point of reference designated as “Orf.” line. The part of pulp chamber or root canal system present below the “Orf.” line in such cases can be designated as a shaded band signifying the extension of pulp chamber below the CEJ or normally expected orifice location and writing “C” instead of “R” or “O” after the fifth line below the root apex of the diagrammatic tooth.

The sequence in which each canal is represented is not fixed, but consideration should be given to present the canals and their intercommunications in a most simplified manner. For example, a “c”-shaped molar system usually starts from mesiolingual canal orifice, passes through mesiobuccal canal, and ends in distal or distolingual canal. The same sequence should be followed while charting this canal system.

Root canals having intercommunications should be placed adjacent to each other to give better understanding. For example, a maxillary premolar having single palatal canal and two buccal canals, the buccal canals should be presented adjacent to each other as they, usually, either bifurcate below the orifice or have intercommunications along their course.

Fig. 4 – Showing the CBCT images and corresponding diagrammatic representation of right maxillary first molar. (a) Transverse section (TS) at cement–enamel junction (CEJ) of tooth 16; (b) TS at orifice level; (c) TS showing two separate canals in the mesiobuccal root; (d) TS showing fusion of the two canals in the mesiobuccal root; (e) section through the buccal roots; (f) buccopalatal section through the palatal root; (g) diagrammatic representation of the case represented.

Although the roots could also have been depicted, it would have led to crowding in the representation. Since keeping the representation simple was one of the main objectives, depicting the roots in the tooth was omitted; instead, a labeled horizontal bar or line, representing a root, can be drawn after the fifth line, grouping the canals present in that root together. Such a representation of roots avoided unnecessary crowding and is useful in certain situations (Fig. 2e and f) like differentiating taurodont from a tooth having bifurcation of root canal without division of roots.

One might argue that we can provide the sections of the root representing the whole canal configuration in a single plane (Fig. 3f, m, and r), but practically it is difficult and almost impossible in curved roots. It is easier to locate the origination, bifurcation, and fusion of the canals in transverse/axial sections of the teeth and calculate the length in longitudinal sections.

The above diagrammatic representation of root canals covers nearly all the presently available major classification systems. Further, it is also able to present most of the clinically relevant information pertaining to the canal configuration. Using the above diagrammatic representation, together with the sectional images, more clinically oriented information can be transferred to the treating clinician than by just simply stating the type of canal system present. It is easy to understand, irrespective of any prior knowledge of other classification systems.

5. Conclusion

Although the above diagrammatic representation does not provide the exact three-dimensional representation of the root canal system, it helps us to get an approximate distribution of the canals in a relatively simple manner. Once mastered, it is an easy and uncomplicated method to apply as a freehand drawing in the given image. It gives us valuable clinical

information about the root canal system, which the other classifications fail to provide.

Conflicts of interest

The authors have none to declare.

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