https://doi.org/10.5272/jimab.2024304.5916

Journal of IMAB
ISSN: 1312-773X
https://www.journal-imab-bg.org

Journal of IMAB. 2024 Oct-Dec;30(4)

Review article

SIZE OF APICAL CONSTRICTION IN DIFFERENT TYPES OF PERMANENT TEETH

Evgeni Stanev, Sevda Yantcheva
Department of Conservative Dentistry, Faculty of Dental Medicine, Medical University of Sofia, Bulgaria.

ABSTRACT:

Background: The final size of the apical root canal preparation has been a contraversion issue for a long time. The enlargement of the apical portion of the root canal may severely affect endodontic prognosis. Preparation of the apical zone to a larger file size may negatively affect the ability to control the filling material during root canal obturation. An excessively expanded apical zone increases the risk of overfilling, which has been shown to be associated with a reduced success rate. This article aims to review research papers on the anatomical natural diameter of the apical root canal constriction, which is the endpoint of the endodontic preparation and should determine the appropriate size of the apical and root canal preparation.

Review Results: In the review, we have included various scientific articles from recent years that comment on the size and shape of the apical constriction in different groups of teeth. We have summarized the results in graphs that give a visual idea of †the differences in the sizes of the different apical constrictions.

Conclusion: The root apex is morphologically a challenging zone. The endodontist should have detailed knowledge of anatomic variation and mechanics challenges involved in treating apical third to manage endodontic therapy effectively. More research is needed to elucidate the influence of the size of the apical constriction on the apical stop preparation.

Keywords: apical constriction, tooth anatomy, apical zone, root canal constriction,

BACKGROUND:

Root canal preparation is a crucial stage of endodontic treatment. It includes the removal of vital or necrotic pulp tissue from the root canal system, parallel to this removal of infected dentin from the root canal walls, and in cases of retreatment - the removal of various types of root canal filling materials. Preparation of the root canals facilitates the entry of irrigants and medications intended for disinfection of the endodontic space. It determines the level and quality of the subsequent obturation of the root canal system.

Knowledge of the anatomical dimensions and form of root canals is mandatory to achieve good results in endodontic treatment. The apical constriction and apical foramen are the main reference points for defining the apical border for instrumentation and root canal filling. Apical constriction is the apical part of the root canal with the narrowest diameter short of the apical foramen. It lies within dentin, just before the first layers of cementum. [1] From the apical constriction or minor diameter, the canal widens as it approaches the apical foramen or major diameter. [2] The shape of the space between the major and minor diameters has variously been described as funnel-shaped, hyperbolic or ‘morning glory’. The mean distance between the major and minor diameters has been determined to be 0.5mm in a young person and 0.67mm in an older individual. Minor diameter is the most suitable place for creating an apical stop-terminus location of root canal therapy. [3] During treatment and obturation of the root canals, the passage of the apical constriction is undesirable. It can cause inflammation and postoperative pain, as well as delay periapical healing. [4] On the other hand, when endodontic preparation is shorter than the apical constriction level, it increases the risk of failure. [5] The patient may feel pain and discomfort, and the tooth may act on the general health of the body as an active field of disturbance. [6]

As early as the 1930s, it was known that the apical constriction was located at the dentin-cementum junction in the apical region [7, 8]. However, several decades later, the anatomy of root canals is not fully understood, including the extent of apical constriction in different types of teeth. [1]

All canals with completed root development and without resorptive processes in the apical area have an apical constriction. [9] Its type, as well as the distance from apical constriction to the root apex, can be different. A major factor in its size and location is the patient's age. In young patients, it is wider, and with age, the diameter decreases, and the distance of apical foramen increases. [10] Obliteration of the apical constriction can also be observed in various pathological processes. [11]

Clinical determination of apical constriction size

Clinically, the area of the apical constriction can be found tactilely with endodontic instruments. The initial file that explores canal anatomy and binds in the canal is usually used to measure apical constriction diameter. Attempting to gauge the size of oval-shaped apical root canals, Wu et al. demonstrated that in 75% of the cases, the initial file contacted only one side of the apical canal wall; in the remaining 25%, the instrument failed to contact any wall. [12] In 90% of the canals, the diameter of the initial instrument was smaller than the short diameter of the canal. Consequently, using the first file to bind for gauging the diameter of the apical constriction as guidance for apical enlargement is unreliable. This problem was recognized, and researchers determined that it could be solved by removing the interferences in the root canal morphology existing in the coronal and middle thirds of the root canal. Early flaring of the root canal before canal exploration removed interferences and increased the initial file size snug at the apex (almost two file sizes greater). Early flaring gives the dentist a better sense of apical canal size. [13, 14, 15]

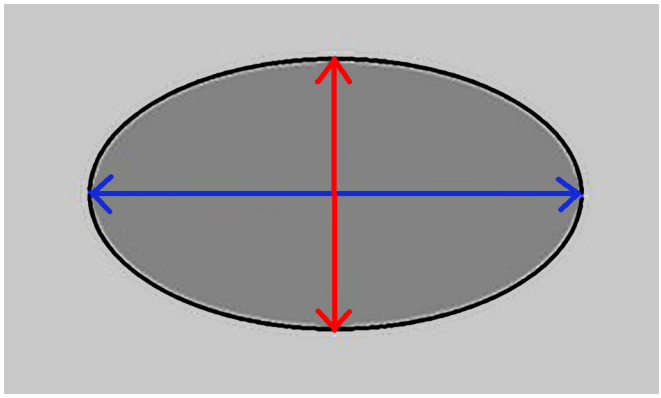
Scientific studies of different groups of teeth and the use of modern measurement techniques give information about the diameter of the apical constriction in general cases. In the clinical work, the individual characteristics of the patient (especially his age) must be taken into account, as well as the diagnosis and the course of the pathological process that led to the need for root canal treatment.

Apical constriction studies

The shape of the apical constriction: The most common shape is oval. Round and irregularly shaped canals are less common (50% of upper molar canals and 59% of lower molar canals are oval shaped. [16] Dummer et al. described several shapes of apical constriction: Parallel 35%, Single 18%, Tapering (Classic) 15%, Flaring 18%, Delta 12% [17]. The authors also confirmed that it is impossible, with complete certainty, to establish the position of the apical canal constriction during root canal therapy.

Some of the authors examine the mean size of the apical constriction, while others detail its narrowest and largest diameters. (fig. 1.)

Fig. 1. The smallest (in red) and largest (in blue) diameters are measured and presented in the results in most studies to represent the apical constriction, which is usually oval. The closer the shape is to a circle, the smaller the difference between two diameters—the more elongated the oval, the more significant.



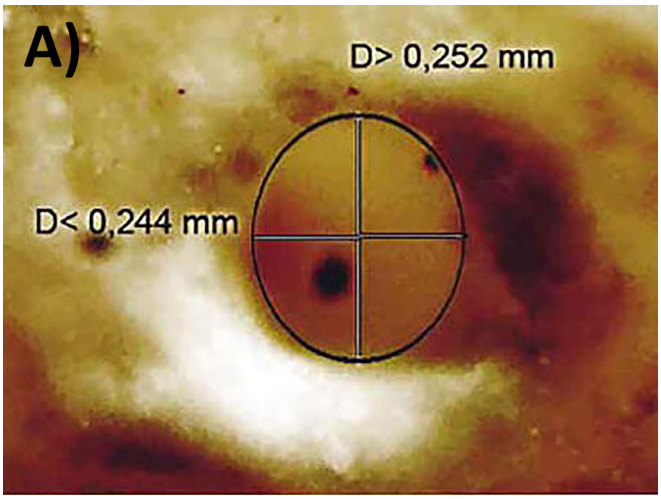
Various methods were used to determine the size of the apical constriction. Some studies have been done with K-files. [18] with different tip diameters. Depending on the file that first tightens at the level of apical constriction (starter file in clinical preparation), the diameter of the constriction is determined. [10, 18] These studies resemble the clinical capabilities of determining the size of the apical constriction. The method determines the narrowest diameter of the apical constriction. It is fast, easy and cheap. However, it does not give information about the shape of the apical constriction and its maximum diameter in cases of oval and irregularly shaped apical constrictions.

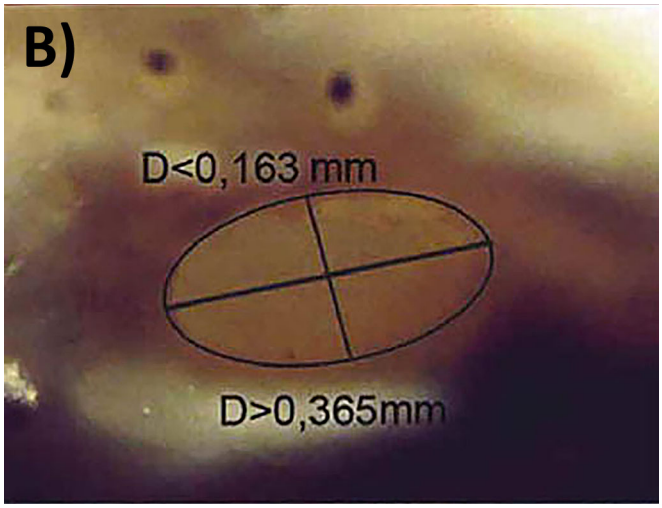
Another method of investigation of apical constriction is micro-computed tomography, where a different resolution can be applied. A voxel is the smallest spatial volume that counts and is analogous to a pixel in digital images. The difference is that the former is a three-dimensional object, while the latter is two-dimensional. Different research teams use different resolutions: 30 μm [19]; 22.9μm [20]; 20 μm [21, 22]; 26.7 μm [23]; 27 μm [24].

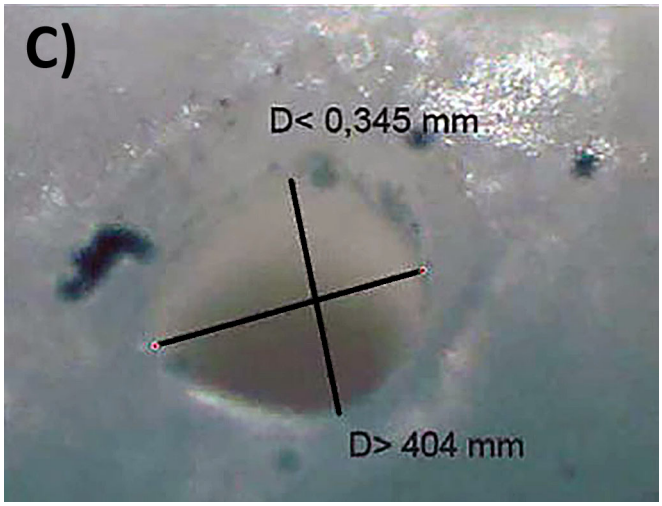
Marroquín et al. use a computerized stereomicroscope for their research. [25]

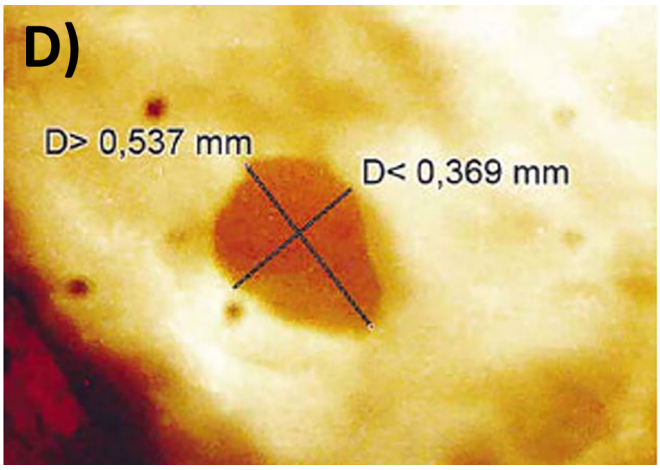
Abarca J, et al. use sections on which they take microscopic photographs with a magnification of x40 and then draw lines on them and determine their length with specialized software. A similar method was used by Behera et al. and Ponce EH, et al. (fig. 2.) [16, 26,27, 28]. Bürgel MO, et al. used scanning electron microscopy. [29]

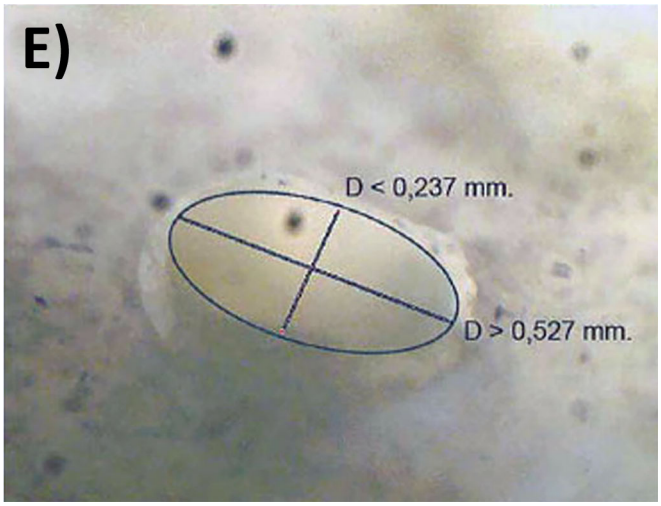
Fig. 2. Shape of the apical constriction : **A)** round, **B** and **E)** oval, **C** and **D)** irregular) [28]











Observing various sources, we detected the most significant interest in investigating apical constriction of lower incisors and molars. This fact is probably due to the anatomical features of these teeth, which is also the reason for the difficulties during their treatment. The size of the apical constriction is most often measured in mm, but in some cases also in ìm. In this article, all dimensions are presented in mm.

REVIEW RESULTS:

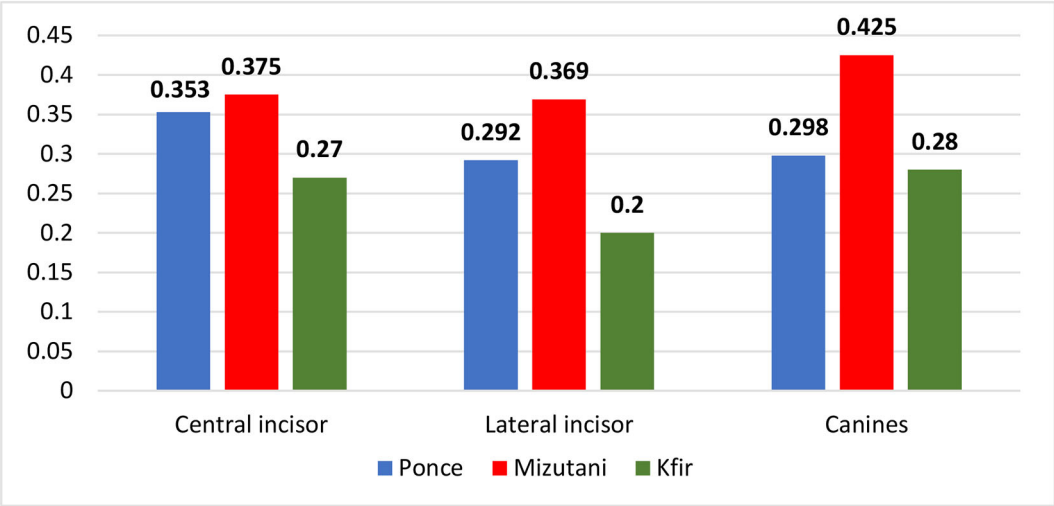
Upper incisors and canines

The study by Ponce EH, et al. includes preparation of histological specimens and optical microscopy. Results showed a mean diameter of 0.298 mm (n=83) for central incisors, 0.292 mm (n=89) for lateral incisors, and 0.353 mm (n=97) for canines. [26]

Mizutani T, et al. found a diameter of 0.425 mm (n=30) for central incisors, 0.369 (n=30) for lateral incisors, and 0.375 (n=30) for canines. [30]

Kfir and Kohl, who use K-files to determine the diameter of the apical taper, give the following data: 0.28 mm for central incisors, 0.20 mm for lateral incisors, and 0.27 mm for canines (fig. 3.) [18]

Fig. 3. Diameter of apical constriction in upper frontal teeth



Olson et al. studied the apical constriction of upper incisors. However, unlike the previous studies, in the results, they divided the teeth depending on the size of the apical constriction into six groups. Each group includes a range of 0.05 mm (50 ìm). [31]

None of the authors considered the apical constriction an oval with different diameters. In Ponce, Mizutani, and Kfir, it is narrowest at the lateral incisors, but the data for the three differ significantly. In Ponce, there is a similarity between the size of central incisors and lateral incisors, while in canines it is more extensive. The opposite is indicated by Mizutani's data, where the similarity is between the size of canines and lateral incisors, while that of central incisors is greater. In the Kfir, there is a similarity in the size of the canines and central incisors, while in the laterals, it is significantly smaller. Olson concludes that in upper incisors, the most common apical constriction is more than 0.20 mm (in more than 40% of cases), which confirms the results of the other authors. Their average values are over 0.20 mm for each of the incisor types. An exception is the size of the lateral incisors in the Kfir study.

Lower incisors and canines

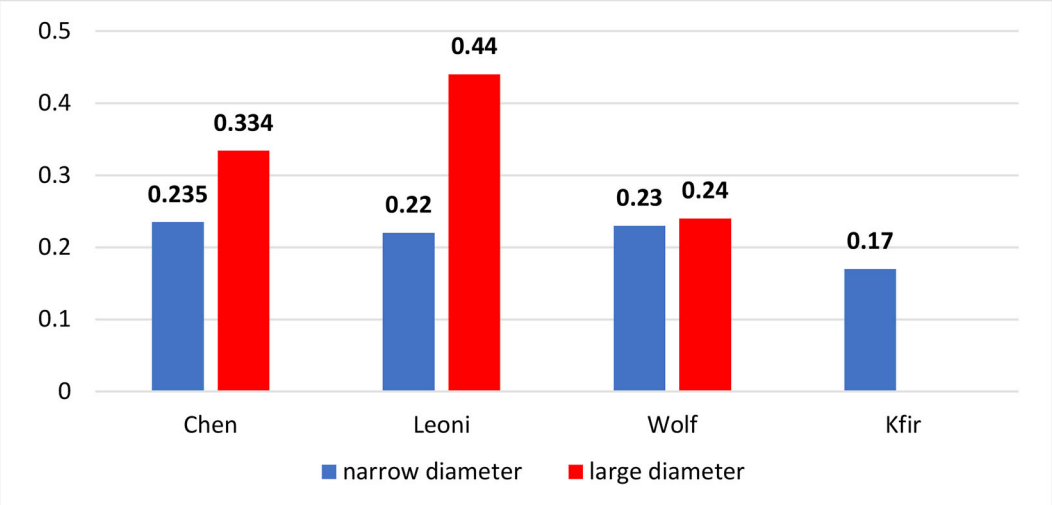
Micro-computed tomography of lower incisors shows that the narrowest part of the canal depends on the type of canal (single, fused, divided). In a study by Chen et al., they included 208 mandibular incisors from patients from China. The results show that the size of the apical constriction varies with endodontic anatomy. In single canals, 0.26/0.37 mm (n=171); in two fused canals, 0.20/0.28 mm (n=54); in two divided canals, 0.16/0.23 mm (n=32). Taking into account the frequency of the different configurations gives an average result of 0.235/0.334 mm. [19]

In a study by Leoni et al., the diameter of lower incisors is measured in various areas of the apical third of the root canal, including 1 mm from the anatomical apex, where the apical constriction is usually located. Data for central incisors show that the diameter averages 0.22 ± 80 mm at its narrowest part and 0.44 ± 190 mm at its widest part. On the other hand, for lateral lower incisors, the values were 0.21 ±50 mm and 0.45 ±190 mm, respectively. [20] From these results, it can be assumed that there are no significant differences between the diameter of the apical constriction in central and lateral mandibular incisors.

Wolf measured apical constriction in 146 mandibular incisors with microcomputer tomography. The patients are from Germany. The data show that the mean size is 0.23±80 mm for their narrow diameter and 0.24 ±100 mm for their broad diameter. In this study, the results show that the apical constriction is circular rather than oval. In the article's conclusion, the authors recommend that the area of anatomical constriction be processed to instruments with numbers 30 or 35, taking into account the individual characteristics of each tooth. [21]

Kfir et al. determined the size of the apical constriction in lower incisors without distinguishing them into central and lateral: 0.17 mm. In dogs, the measured size averaged 0.28 mm (fig. 4.) [18]

Fig. 4. Diameter of apical constriction in lower incisors



In apical constriction of mandibular incisors, there are differences in the data from different studies, both for the shape and the large diameter of the apical constriction in mandibular incisors. According to Wolf, the shape is oval, and the two values for minimum and maximum diameter are close. In the other authors, the shape is oval, and in Leoni, the size of the large diameter exceeds twice that of the small diameter. In Chen, there is a difference between the large and small diameters, but the difference is not significant. The size found by Kfir is much smaller (more than 0.05 mm) than the data of other researchers.

There is little data on apical constriction in lower canines.

Premolars

Abarka J, et al. studied the apical constriction of upper premolars in 125 teeth, with about half being first premolars and the rest second. Their shape is oval in 72%, irregular in 19% and round in 9% of cases. The irregular shape is most common in single-canal second premolars, while the oval shape is most common in the palatal canal of the first premolar. The average diameter is 0.27/0.41 mm. [16]

For lower premolars, Bürgel MO, et al. analyzed 45 teeth (25 first premolars and 20 second premolars). The mean apical foramen size was 0.149/0.915, but the investigators did not measure apical constriction. [29]

Kfir A, et al. determine the average size of the apical constriction in premolars as follows [18]:

Upper premolars with one apical foramen: 0.30 mm.

Canine premolars with two apical foramina: 0.14 mm.

Lower premolars with one apical opening: 0.23mm.

Lower premolars with two apical openings: 0.18mm.

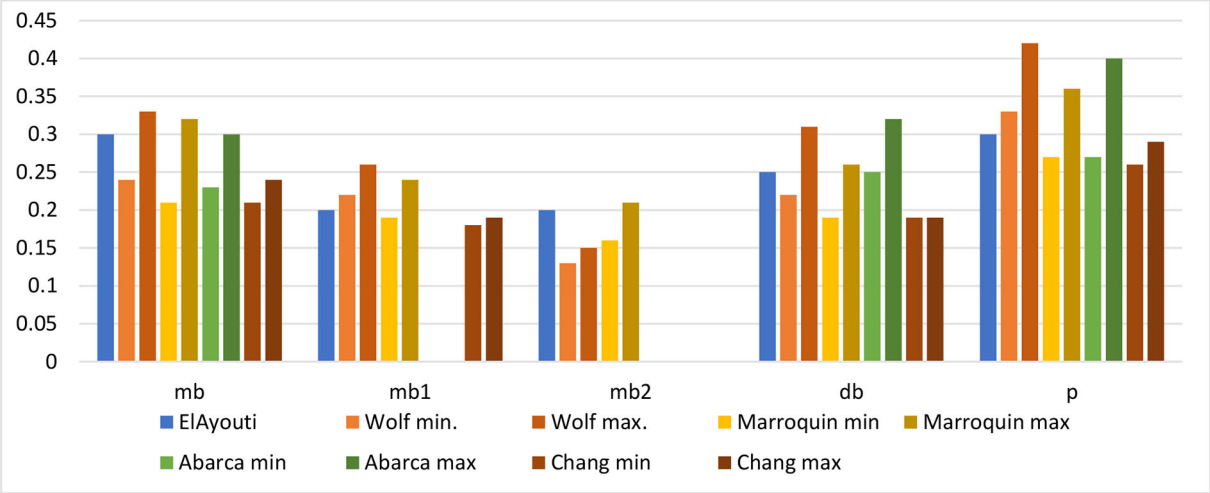
There is little data on apical constriction in premolars. The results show that the configuration of the root canals and the number of apical openings is essential. According to Abarka's data, both with one apical opening and two, the apical constriction of the upper second premolars is wider than that of the first. Moreover, the apical constriction with two apical openings is always narrower than in cases with only one opening. Kfir's results confirm that with two apical foramina, the apical narrowing is always less than when there is only one. However, in his study, the differences in size are significantly larger, reaching 0.16 mm for upper premolars and 0.05 mm for lower.

Upper molars

Of greatest interest are the dimensions of the first and second molars. Wisdom teeth have a more complex and varied anatomy and are less likely to undergo endodontic treatment. Kfir studies with a K-file gave mean values for the vestibular canals of 0.16/0.27mm and the palatal canals of 0.26/0.35mm. [18]

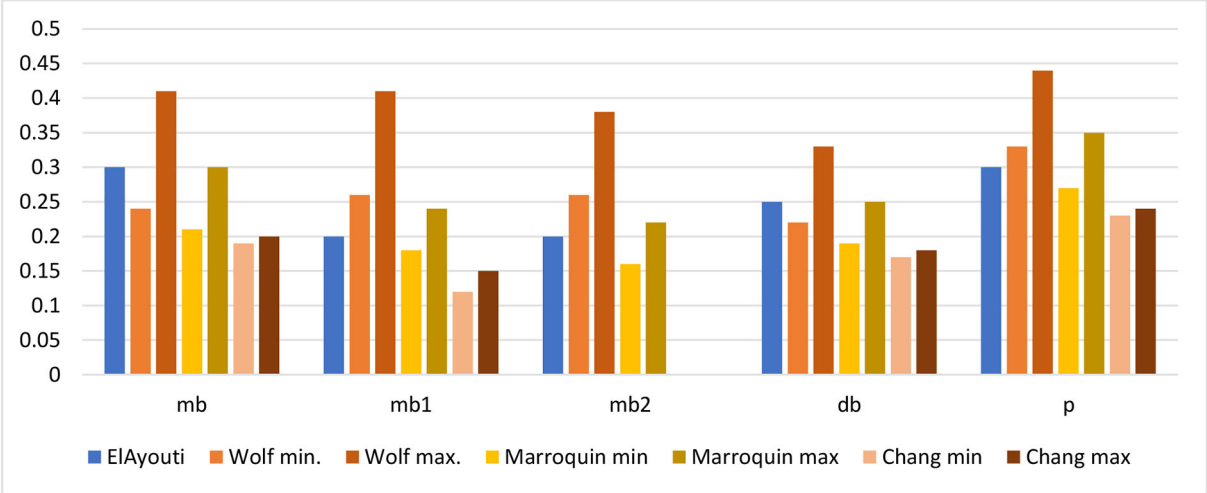
Meder-Cowherd L, et al. examined only the palatal canal of maxillary first molars. They found mean values of 0.53 mm for the smallest diameter and 0.59 mm for the largest diameter of the apical constriction (fig.5.) [32]

Fig. 5. Diameter of apical constriction in the upper first molar



In all study results, apical constriction was the least at MB2 and the next largest at MB1. Next is the constriction of the DB, and in the case of one MB root canal. Only in Abarca's studies, the apical constriction of the DB canal is wider than that of MB. The largest is the constriction of the palatal canal. Only in ElAyouti's research is its average size equal to the MB size. In studies in which two diameters are reported, there is a difference between their values. Only with Chang is the difference between the two diameters much smaller. Kfir's data also confirm that the size of the apical constriction in the palatal canal is greater than that of the vestibular. Meder-Cowherd's data, which refer only to the palatal canal, have much higher values than other researchers. (fig. 6.)

Fig. 6. Diameter of apical constriction in the upper second molar



In the upper second molar, the differences between the apical constriction of the different mediovestibular canals are not as pronounced as in the first molar. The differences are not significant between the mediovestibular channels and the distovestibular. Only the palatal canal has a more significant apical constriction than the others. Only in ElAyouti's research is its average size equal to the size of the MB, as is the case with the first molar. In Wolf's study, the apical constriction is more elongated in cross-section. At the same time, in the other authors, the difference between the major and minor diameters is more negligible (the shape is closer to a circle). In Chang's study, the canals are nearly circular. In Marroquín's study, a high similarity was observed between data for the upper first and upper second molars. The data for upper third molars show a slightly smaller size of the apical constrictions; only in MB1 is the size larger.

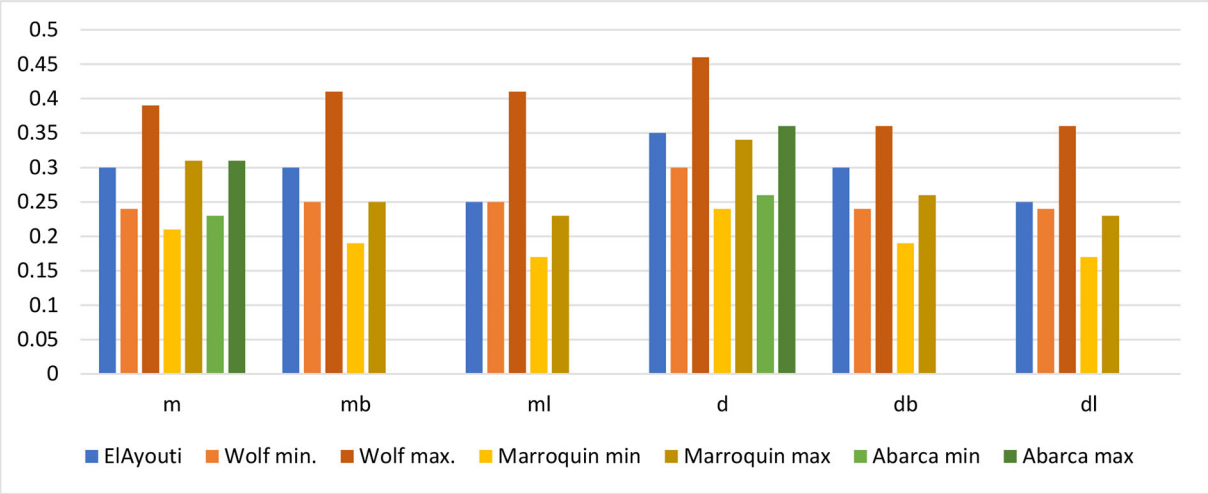
Lower mollars

Kfir studies with a K-file show that in one root canal in the medial root, the diameter of the apical constriction is 0.16/0.28 mm, and for the distal 0.25/0.36 [18]

The results show that in lower molars with one canal in a root, the apical constriction is wider than in cases with two separate canals in the same type of root. Only in Wolf's study, in the medial canals, were the apical constrictions almost the same whether the canals were one or two. The results of Wolf, Marroquin, and Abarca were nearly identical in the cases of a single root in the medial canal, while when analyzing the distal canal, Wolf's data showed

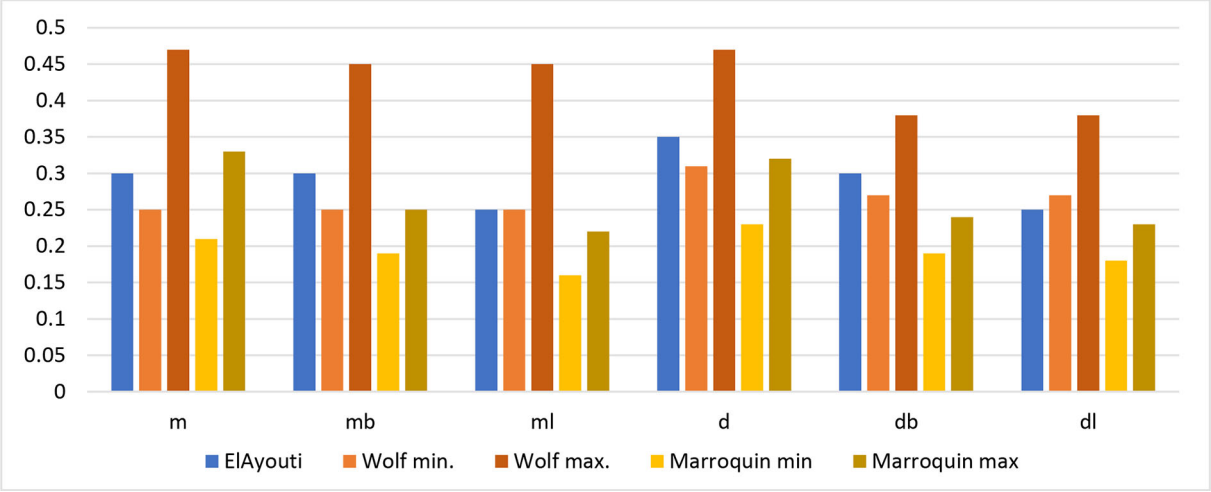
a wider apical constriction. In the presence of two canals in the same root, Wolf and Marroquin showed that apical constrictions were almost identical. However, ElAyouti measured that buccal root canals had a wider apical constriction than lingual root canals. Wolf reports a more significant difference in the diameters of the apical constrictions - the shape of constriction here is more elliptical than in upper molars (fig.7.).

Fig. 7. Diameter of apical constriction in the lower first molar



In contrast, in Marroquina, the difference between major and minor diameters of apical constriction is less (they are rounder). However, none of the variants observed equality between the major and minor diameters (circular shape of the apical constriction). Kfir's results are similar to those of the other authors (fig.8.)

Fig. 8. Diameter of apical constriction in the lower second molar



In both first and second molars, the presence of two root canals in one root implies a narrower size of the apical constriction. Again, the exception is the medial canal in Wolf's study, where the minor diameter in one medial canal matched the minor diameter in two medial canals. There is also a match in ElAyouti's study between the apical constriction in one medial canal and that in the mesiobuccal in the case of two medial canals. Like in the study of the first lower molar, the presence of two canals suggests that the apical constriction of the buccal will be greater than that of the lingual. Such are the results of Marroquine's study. A significant difference between the minor and major diameters of the apical constriction was observed in the Wolf and Marroquine studies, which were more pronounced in the Wolf study.

Apical size of preparation

The clinical concept of apical preparation aims at complete circumferential removal of dentine. The traditional rule is to prepare the root canal at the level of apical constriction at three sizes beyond the first file that bends at that region (working length).

Weiger R, et al., in a laboratory study, calculated that enlargement to initial diameter plus 0.4mm in molar palatal and distal root canals and 0.3mm in mesio-buccal, mesio-lingual and disto-buccal root canals of

molars would be necessary to achieve complete preparation of the canal circumference in 78% and 72% of the canals, respectively. Preparation to initial diameter plus 0.6mm would result in 95% of the cases being prepared completely but included a high risk of perforations. [33]

Even though the use of nickel-titanium (Ni-Ti) rotary preparation techniques allows curved canals to be enlarged to sizes 45-80, the effect of such preparation on tooth structure should be studied. The increased flexibility of Ni-Ti files reduces the deviation of the canal curvature from the original shape. [34] It also seems that apart from the clinicians' skill, there are many procedural risks related to the enlargement of the apical part of the canal. [35]

CONCLUSION:

The root apex is a morphologically challenging zone. To manage endodontic therapy effectively, the endodontist should have detailed knowledge of the anatomic variation and mechanics particularity involved in treating the apical third. This study included data collected from human teeth of people of different ages and regions, which likely affected root anatomy and the size of the apical constriction. In addition, the data analyzed were obtained using various methods. These facts present limitations for drawing definitive conclusions. More research with clearly defined parameters and research methods is needed to clarify the influence of the size of the apical constriction on the preparation of the apical stop and to clarify whether it is mandatory to include the entire perimeter of the physiological constriction in the preparation or whether it is more important to preserve the root thickness in this area.

REFERENCES:

1. Kuttler Y. Microscopic investigation of root apexes. *J Am Dent Assoc.* 1955 May;50(5):544-52. [PubMed]

2. Vertucci FJ. Root canal morphology and its relationship to endodontic procedure. *Endodontic Topics.* 2005 Mar;10(1):3-29. [Crossref]

3. Peters OA. Current challenges and concepts in preparation of root canal systems: A review. *J Endod.* 2004 Aug;30(8):559-567. [PubMed]

4. Tinaz AC, Alacam T, Uzun O, Maden M, Kayaoglu G. The effect of disruption of apical constriction on periapical extrusion. *J Endod.* 2005 Jul;31(7):533-5. [PubMed]

5. Negishi J, Kawanami M, Ogami E. Risk analysis of failure of root canal treatment for teeth with inaccessible apical constriction. *J Dent.* 2005 May;33(5):399-404. [PubMed]

6. Dencheva M. [Perturbation fields in the maxillofacial region in hemodialysis and renal transplant patients – a behavioral algorithm.] [dissertation] Sofia (Bulgaria): FDM, Sofia. 2010. [in Bulgarian]

7. Skillen WG. Why root canals should be filled to the dentinocemental junction. *J Am Dent Assoc.* 1930;17(11):2082-2090. [Crossref]

8. Grove CJ. Why root canals should be filled to the dentinocemental junction. *J Am Dent Assoc.* 1930 Feb;17(2):293-296. [Crossref]

9. Schell S, Judenhofer MS, Mannheim JG, Hülber-J M, Löst C, Pichler BJ, et al. Validity of longitudinal sections for determining the apical constriction. *Int Endod J.* 2017 Jul;50(7):706-712. [PubMed]

10. ElAyouti A, Hülber-J M, Judenhofer MS, Connert T, Mannheim JG, Löst C, et al. Apical constriction: location and dimensions in molars-a micro-computed tomography study. *J Endod.* 2014 Aug;40(8):1095-9. [PubMed]

11. Torres A, Shaheen E, Lambrechts P, Politis C, Jacobs R. Microguided Endodontics: a case report of a maxillary lateral incisor with pulp canal obliteration and apical periodontitis. *Int Endod J.* 2019 Apr; 52(4):540-549. [PubMed]

12. Wu MK, Wesselink PR, Walton RE. Apical terminus location of root canal treatment procedures. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2000 Jan;89(1):99-103. [PubMed]

13. Stabholz A, Rotstein I, Torabinejad M. Effect of preflaring on tactile detection of the apical constriction. J Endod. 1995 Feb;21(2):92-4. [PubMed]

14. Leeb J. Canal orifice enlargement as related to biomechanical preparation. J Endod. 1983 Nov;9(11): 463-70. [PubMed]

15. Contreras MA, Zinman EH, Kaplan SK. Comparison of the first file that fits at the apex, before and after early flaring. *J Endod.* 2001 Feb; 27(2):113-6. [PubMed]

16. Abarca J, Zaror C, Contreras W, Jadue S, Olguin C, Steinfort K, et al. Morphology of the Physiological Apical Foramen of Maxillary Premolars. *Int J Morphol.* 2018 Mar;36(1):164-168. [Crossref]

17. Dummer PM, McGinn JH, Rees DG. The position and topography of the apical canal constriction and apical foramen. *Int Endod J.* 1984 Oct;17(4):192-8. [PubMed]

18. Kfir A, Rosenberg E, Fuss Z. Comparison in vivo of the first tapered and nontapered instruments that bind at the apical constriction. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2006 Sep;102(3):395-8. [PubMed]

19. Chen M, Wang H, Tsauo C, Huang D, Zhou X, He J, et al. Micro-computed tomography analysis of root canal morphology and thickness of crown and root of mandibular incisors in Chinese population. *Clin Oral Investig.* 2022 Jan;26(1):901-910. [PubMed]

20. Leoni GB, Versiani MA, Pécora JD, Damião de Sousa-Neto M. Micro-computed tomographic analysis of the root canal morphology of mandibular incisors. *J Endod.* 2014 May;40:710-6. [PubMed]

21. Wolf TG, Stiebritz M, Boemke N, Elsayed I, Paqué F, Wierichs RJ, et al. 3-dimensional Analysis and Literature Review of the Root Canal Morphology and Physiological Foramen Geometry of 125 Mandibular Incisors by Means of Micro-Computed Tomog-

raphy in a German Population. *J Endod.* 2020 Feb;46(2):184-191. [PubMed]

22. Wolf TG, Paqué F, Sven Patyna M, Willershausen B, Briseño-Marroquín B. Three-dimensional analysis of the physiological foramen geometry of maxillary and mandibular molars by means of micro-CT. *Int J Oral Sci.* 2017 Sep;9(3):151-157. [PubMed]

23. Chang JWW, Manigandan K, Samaranayake L, NandhaKumar C, AdhityaVasun P, Diji J, et al. Morphotypes of the apical constriction of maxillary molars: a micro-computed tomographic evaluation. *Restor Dent Endod.* 2022 May;47(2):e19. [Crossref]

24. Schell S, Judenhofer MS, Mannheim JG, Hülber JM, Löst C, Pichler BJ, et al. Validity of longitudinal sections for determining the apical constriction. *Int Endod J.* 2017 Jul;50(7):706-712. [PubMed]

25. Marroquín BB, El-Sayed MA, Willershausen-Zönnchen B. Morphology of the physiological foramen: I. Maxillary and mandibular molars. *J Endod.* 2004 May;30(5):21-8. [PubMed]

26. Ponce EH, Fernández, JAV. The cemento-dentino-canal junction, the apical foramen, and the apical constriction: evaluation by optical microscopy. *J Endod.* 2003 Mar;29(3): 214-9. [PubMed]

27. Behera A, Santhanam A, Sherlin HJ, Jayaraj G, Don KR. Estimation of Age Using Dimensions of Apical Foramina of Teeth. *J Evolution Med Dent Sci.* 2021 Mar 08;10(10):705-711. [Crossref]

28. Abarca J, Zaror C, Monardes H, Hermosilla V, Muñoz C, Cantin M. Morphology of the physiological apical foramen in maxillary and mandibular first molars. *Int J Morphol.* 2014 Jun;32(2):671-677. [Crossref]

29. Burgel MO, Borba MGD. [SEM analysis of apical anatomy of mandibular premolars.] [in Portuguese] RFO UPF. 2011;16(1):49-53. [Internet]

30. Mizutani T, Ohno N, Nakamura H. Anatomical study of the root apex in the maxillary anterior teeth. *J Endod.* 1992 Jul;18(7):344-7. [PubMed]

31. Olson DG, Roberts S, Joyce AP, Collins DE, McPherson JC 3rd. Unevenness of the apical constriction in human maxillary central incisors. *J Endod.* 2008 Feb;34(2):157-9. [PubMed]

32. Meder-Cowherd L, Williamson AE, Johnson WT, Vasilescu D, Walton R, Qian, F. Apical morphology of the palatal roots of maxillary molars by using micro–computed tomography. *J Endod.* 2011 Aug;37(8):1162-5. [PubMed]

33. Weiger R, Bartha T, Kalwitzki M, Löst C. A clinical method to determine the optimal apical preparation size. Part I. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2006 Nov;102(5):686-91. [PubMed]

34. Figdor D, Sundqvist G. A big role for the very small—understanding the endodontic microbial flora. *Aust Dent J.* 2007;52(1 Suppl):38-51. [PubMed]

35. Weine FS. Endodontic Therapy. 5th edition. Mosby. January 15, 1996. [Internet]

Please cite this article as: Stanev E, Yantcheva S. Size of apical constriction in different types of permanent teeth. *J of IMAB.* 2024 Oct-Dec;30(4):5916-5924. [Crossref - https://doi.org/10.5272/jimab.2024304.5916]

Received: 30/07/2024; Published online: 10/12/2024

Address for correspondence:
Evgeni Stanev
Department of Conservative Dentistry, Faculty of Dental Medicine, Medical University of Sofia;
1, Sv. Georgi Sofiyski Str., Sofia, Bulgaria,
E-mail: stanev242@gmail.com,