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APICAL CONICAL SIZE OF THE ROOT LENGTHS: AN ANATOMICAL COMPARATIVE STUDY OF SIGNIFICANCE TO MINIMALLY INVASIVE ENDODONTICS

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Abstract. Introduction: *The apical thirds of the roots and their cone-shaped parts are neglected into dental literature and education. Apical foramen is the only anatomical structure in the internal part of the root conus with construction described in textbooks, atlases and monographs.* ***Aim:*** *The aim of the study is to measure the size and proportion of the longitudinal part of the conic shape of the roots into different groups of teeth for maximum saving of dentine and sound active root surface for prevention of fractures and cracks.* ***Materials and Methods:*** *158 upper and lower front teeth are included in the study. Lengths were measured twice for each tooth with endodontic files and disks as follows: the whole tooth, the root from neck to apex and the conical part of the root. Exclusion criteria consisted of: teeth with broken cusps, roots, or incisal ridges, large apical resorptions higher than 1.5 mm, fluorotic teeth, teeth with abrasion, and lateral root resorptions larger than 1 mm.* ***Results:*** *The null hypothesis for a smaller deviation of the length of the cone part from the roots compared with the whole root in the total longitudinal size of the roots was proved. This cone part was measured to be between 4.3-6.3 mm distance from the apex in upper and lower front teeth and premolars. The proportion to the whole length of the roots varies from 25% to 48.8% ($p<0.05$). The statistics were performed with the more sensible Levene's test for mean differences.* ***Conclusions:*** *Active rotary machine root canal preparations in the apical zone, even at 1-2 mm away from the apex can decrease significantly the amount of apical dentine and can lead to cracks in this area. Bigger sizes of posts can overload the roots in this zone and their safe placement is essential.*

Key words: *apical patency, apical size, endodontic anatomy, minimally invasive endodontics*

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INTRODUCTION

The shape and size of the external cone in the apical part of the dental roots have been ignored in most textbooks and endodontic atlases. It is related not only to variables, but also to the position of the apical foramen inside the conus, which varieties has been described to fluctuate by up to 6 mm from the anatomical apex and are related to the apical patency. The persisting dogma is related to the "apical third" of each root in endodontic treatments. Active root canal machine-driven preparation in the apical zone, even at 1 or 2 mm away from the apex, can decrease significantly the amount of apical dentine. A side effect reflects into a decrease in the active root surface (thinner dentine) and can lead to cracks in this area. This finding plays a key role in the successful conservative endodontic treatments. The consequences of underinstrumentation include infections, persisting microorganisms in the root canal system, and periapical infections treatable with retreatment. The side effects from overinstrumentation are permanent, and some of them are nearly impossible to be corrected: resorptions, overfilling, bone lesions, lateral and apical periodontitis, teeth mobility, cracks and root fractures, etc.

The internal root image – construction of apical foramen, is described in many endodontic textbooks [1, 17, 18, 22, 23, 25]. In most monographs, the external anatomy along the roots is not studied at all [2, 3, 8-10, 19, 20].

In the era of machine-driven endodontics with Ni-TI files by definition used with irrigants – 1-2.5% NaOCl, larger numbers of gutta percha cones used with cold condensation techniques, the outcomes of endodontic treatments are showing lower survival rates of nonvital teeth [13, 15, 16]. The lack of sound root dentin is increasing the number of extracted nonvital teeth [5-7]. The step back technique is in use in all dental schools in the EU and USA, although very often the indications are ignored and the exclusion criteria are not carefully applied. The outcomes are survival rates in endodontically treated teeth down to 7.5 years [16, 21]. With the classical standard RC preparation technique, the survival rates were 35-55 years. The failures nowadays are from 14% in Germany to 50% in Denmark in 2000, and the success rates from 21.7% to 63% [13-16, 21]. Most of data on survival rates after endodontic treatments are obtained from faculties and universities and very rarely from private dental offices, where the rates of success are not established by the practitioners. Failures are due to: overheating the external root surface and/or aggressive irrigation and preparation protocols, leading to apical periodontitis [1], internal, lateral and 95% of apical resorptions [1]. Teaching about internal apical patency is ongoing into 50% of USA dental schools since 1997. In USA and most countries in the EU, the main root canal obturation method is lateral cold condensation – 89.6%, long before the apical patency teaching [24]. The activation of osteoclasts during the mechanical and traumatic procedures can provoke local inflammatory reactions. It is logical that in the weakest area of the cone-shaped part of the root cracks, fractures and resorptions can occur.

Often, the roots are overloaded with large sizes of posts, which are "riding" above this zone of the tooth. One of the reasons is that endodontic microscopes give the operators an enlarged, wrong image about volumes in millimeters, where the reality format is L1 10-12 mm (1 cm), L2 5-6 mm (1/2 cm) and mesiodistal thickness of 3-4-5 mm into one root.

The aim of the study was to measure the size and proportion of the longitudinal part of the conic shape of the roots into different groups of teeth for maximum saving of dentine and sound active root surface for prevention of fractures and cracks.

MATERIALS AND METHODS

One hundred fifty-eight matured, fully mineralized front teeth, genetic material used in the preclinical course of the Conservative Dentistry Department, collected from local dental practices, were included in the study. They are acquired from the Bulgarian population and mainly from the local genome. All the teeth were distributed in groups according to the dental formula. The measurements were performed with endodontic files with rubber stoppers and endodontic rulers. Exclusion criteria consisted of: teeth with broken cusps, roots or incisal ridges, large apical resorptions higher than 1.5 mm, fluorotic teeth, teeth with abrasion, lateral root resorptions larger than 1 mm. The methodology of measurements is shown on Figure 1 a-d.

Statistical Analysis

The statistical analysis of Levene is a modified ANOVA analysis of variance, equality of variances for quality of paired samples, where $p<0.05$ is having enough variance in the sample to account for possible mean differences. The methodology is more sensible than the t-test where p-values start from $p<0.10$.

RESULTS

The mean values from two measurements of the lengths and sample sizes compared with larger sample size studies are shown in Table 1.

The data is compared to previous data found in Bulgaria [1, 2] and other published studies (Germany, USA, etc.) [18-20, 23, 24]. A pilot study on front teeth was undertaken in advance, where the proportion of the conical part was between 38.8%-44.6%, and after a power curve, this study was completed. In the present study, the data on front teeth is compared with Boyanov et al. [2].

In Table 2, the statistical analysis is presented. The p-value is set with a level of significance 0.028

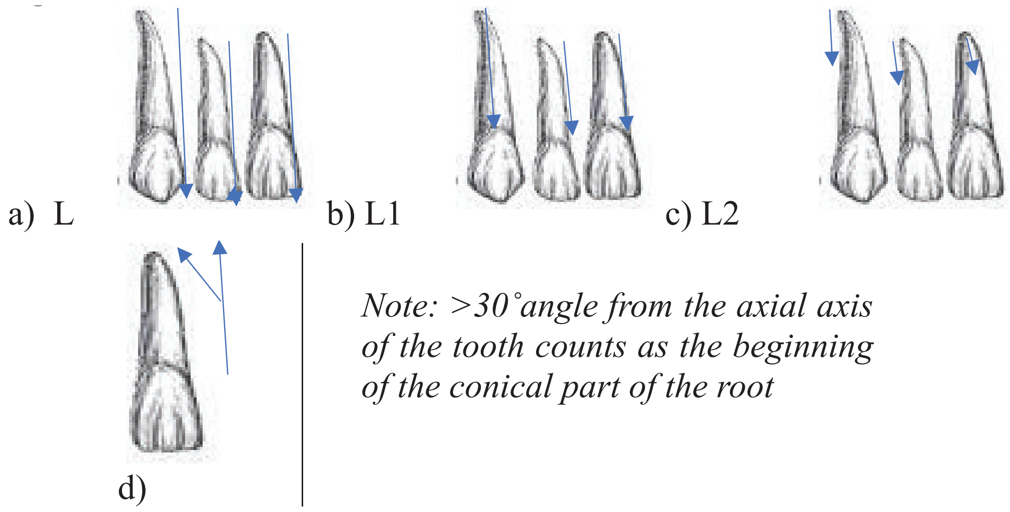


Fig. 1 a-d. Measurements of the whole tooth, the root and the conical root part

Table 1. Means from two measurements of the lengths in mm, sample sizes, compared with larger sample size studies

Teeth (n=415)	L/Boyanov (1951)	L/ Moss Stock (1995)	L/ Volk (1988)	L/ B, Y	L1/Boteva, Yancheva	L1/ Boyanov (1951)	L2/ LCo:LR
11, 21 (N= 26)	21.4	22.5	22.2	22.43	12.70*	12.1	6.15*/ 49%
12, 22 (N=18)	21.4	22.0	21.5	23.69	14.94*	12.3	5.56*/ 37%
13, 23 (N=14)	25.3	26.5	25.6	27.3	17.0*	15.7	6.30*/ 37%
14, 24 (N=10)	20.3	20.6	20.7	21.5	13.4*	13.3	4.55*/ 34%
15, 25 (N=14)	20.9	21.5	20.8	21.4	13.8*	13.9	5.00*/ 36%
31, 41 (N=25)	20.1	20.7	20.3	20.1	12.0*	12.2	3.00*/ 25%
32, 42 (N=18	22.4	21.1	21.8	22.9	14.2*	12.9	4.30*/30%
33, 43 (N=10)	24.4	25.6	25.1	23.6	14.7*	14.5	4.3*/ 29%
34, 44 (N=13)	21.4	21.6	21.5	22.0	13.6*	14.0	4.8*/ 35%
35, 45 (N=12)	21.3	22.3	21.9	21.4	13.6*	14.5	5.2*/ 38%

Abbreviations: L = length of teeth; L1 – root length; L2 – length of the conical part in mm and proportion to the root – L1: LCo:LR (%)

Table 2. Data analysis and number of samples in each group of front teeth

Teeth Groups	Root part		SD (L1)mm	SD (L2) mm
	Root (L1) N	Conus (L2) N		
11,21	26	26	1.33	0.97
12,22	16	16	1.40	0.54
13,23	14	14	2.13	0.75
14,24	10	10	2.11	0.61
15,25	14	14	1.75	0.80
31,41	25	25	1.39	0.45
32,42	18	18	1.21	0.60
33,43	10	10	0.75	0.44
34,44	13	13	1.49	0.66
35,45	12	12	1.85	0.83
TOTAL	158			
Mean/mm	13.84	4.84	1.58	0.71
Variables SD mm	1.99	1.14	0.41	0.21

(p<0.05). The differences are related as a proportion of the conical shape part from the total root length. This proportion varies from 25% into lower first incisor to 48% into the upper first incisor (table 1, L2). For upper teeth, this is always more than 1/3 and up to 1/2. For lower teeth, it is from 1/4 up to 1/3.

The results from the test of Levene on the variation between the root length and conical part length were found to be with the level of significance *p<0.05*. The conical apical part on the external root surface in mm is 4.5-6.5 ± 0.2 mm in all incisors and premolars. This includes the apical patency, with the apical foramen. The proportion of this apical part is between *34-48.8% in upper teeth and between 25 and 38% in the lower teeth*. This is quite different from the usually accepted in endodontics *dogma for "the apical third"* of each root! The NiTi rotary instruments are a set of sizes and are usually applied equally for each root canal. Such data is an excellent explanation of the endodontic treatment failures in the era of large machine endodontic preparation of root canals with the protocol requirement for NaOCl. These findings are noticeable also with a reflection of the use of posts. Practically, the safe space, without additional tensions on the root canal, is 6-7 mm from the neck of a tooth to the beginning of the conical part. In the upper first premolar and lower first incisors, "safe spaces" are under discussion due to the anatomy of the teeth (thin roots and a small amount of dentin).

Figure 2 presents the data from Table 2 for better visual expression of the differences between the investigated proportions.

DISCUSSION

The importance of knowing and better understanding of the sizes and the anatomy of the conical part in the different groups of teeth is related to the prevention of iatrogenic errors. Apical periodontitis affects 20 to 50% of the populations in different countries (Fig. 3 a, b). Among general dentists, the proportions of post endodontic treatment periodontitis are between 24.5% and 65.8% in different countries [6, 13]. Error-free endodontic treatments are in 34% to 68.9% of the teeth in different studies. Underfilling of the root canals is observed in 9-14% to 31.1% of the

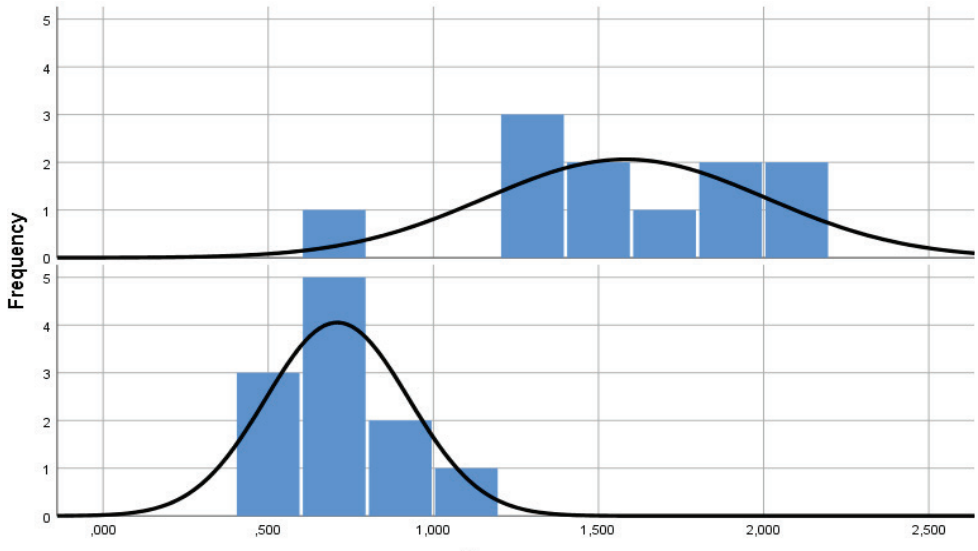


Fig. 2. Frequency of variables – SD, in different groups of teeth. The upper graph depicts the root length (L1) and the lower graph depicts the conical part (L2)

a) 

b) 

Fig. 3 a, b. Comparative anatomy of upper front incisors and upper first premolars. Most of them were extracted for apical periodontitis complications, overfilling – up to 49.9%, but apical transportation – in 2.3-19% and apical perforation in 9.2-18.2% of all cases. Overall, the results show that more than 50% of the endodontic treatments are related to the wrong protocol and approach to the apical conical part of the root (Fig. 4 a, b). Broken instruments are found in 6-10% of the cases, usually also in the second part of the root canal. Overall, similar cases account for 43-47% of the complications [13-16]. Standard protocols, machine-driven root canal preparations and multiple irrigations are related to iatrogenic pathological conditions in this part of the teeth, statistically proven more often in the lower mandibular molars and upper anterior teeth. Usually, the outcomes from the complications and errors in the conical part of the teeth are directly related to the periapical bone and affect the periodontal ligaments.

The patient characteristics are unknown. The size and shape of teeth can vary considerably and can be related or not to the anthropology of the individuals. The collected teeth were healthy, without fluorosis, resorptions, or abrasion.

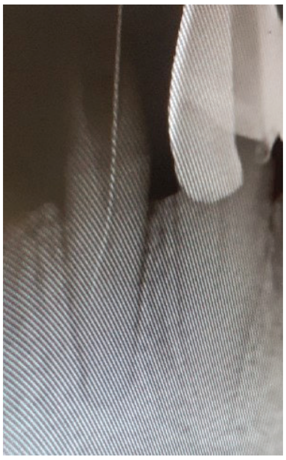
Apical foramen has been described as 0.4 mm to 1.2 mm, or 0.5 to 1.01 mm, 0.86 to 1.01 mm, with three types: normal appearance, with a narrow delta part, and parallel. In 17 publications, the distance between the anatomical apex and apical foramen (Table 3) is set to be up to 1 mm. Burch (1972) found an average distance of 0.59 mm in 877 teeth. In all the studies, the variations are obviously less than 1%.

Only Ingle and Backland [17] accept 2 mm as a golden standard for a security factor. The Ingle's monographs, published in many different editions and thousands of books in the 80s and 90s of the 20th century, are considered a classical endodontic school and scientific background even now. Our findings on apical foramen were focused on 186 molars with 558 roots, where 17.7% were from 1 to 3 mm away from the anatomical apex, and some of them were more than 3 mm and up to 6 mm away. When nearly 1/5 – 20% of the foramens are placed 1 or more mm away, the 2-mm security factor based on Ingle's findings sounds more logical, when is possible. In cases with periodontitis, smear layers, and apical resorptions, it is not always possible.

CONCLUSIONS

The conical part of the roots varies from 25% in lower front teeth up to 48.8% in the upper front teeth from the longitudinal size of the roots, and is a variable part of the active root surface – 4.3-6.3 mm.

Active large root canal machine-driven preparations in the apical zone, even at 1-2 mm away from apex can decrease the amount of apical dentine and lead to cracks in this area. Especially risky

a) 

b) 

Fig. 4 a, b. X-ray immages of complications during a two-week endodontic tratment from a wrong approach to the conical part of the root. Between the visits the bone and root resorptions, total periodontitis with acute symptoms appered and were treated with conservative methods

Table 3. Distance of apical foramen to anatomical apex – various authors' measurements

Author	Measurement data
Messing, Stock (1988) [18]	0.5-0.7 mm, up to 3 mm
Ingle, Backland (1994) [17]	Up to 2 mm
Boteva (2014) – 778 teeth [1]	0.5-3 mm/ up to 5-6 mm
Torabinejad, Walton (2002) [25]	0.5-1 mm

are the techniques with concentrations of NaOCl higher than 1%.

Bigger sizes of posts can overload the roots in this area and their safe placement related to the conical part size is essential.

Conflict of Interest Statement: The authors declare no conflicts of interest related to this work.

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***Ethical Statement:** This study has been performed in accordance with the ethical standards as laid down in the Declaration of Helsinki. The genetic material used is from the preclinical course of the Conservative Dentistry Department, collected from local dental practices.*

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