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On the size of apical foramen in anterior teeth, bicuspids and molars

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SUMMARY

The present authors have used a replica method to obtain area size measurements for the apical foramen in 4,613 human permanent teeth, and have obtained the following results:

1. **The morphology of the apical foramen is rich in variety which make it difficult to express its accurate size using foramen diameter measurement. It is therefore more appropriate to determine its size as an area measurement.**
2. **Much variation was observed in the size of the apical foramen even for teeth of the same type. It was, however, also observed that the foramen is smaller in smaller types of teeth and larger in larger types of teeth. It was also observed that, in teeth of the same type, those with a greater number of roots have smaller foramen than those with a smaller number of roots.**

KEY WORDS:

Apical foramen - Replica method - Foraminal area size

RÉSUMÉ

Les auteurs ont utilisé la méthode des répliques pour mesurer la surface des foramen apicaux de 4.613 dents humaines définitives. Les résultats obtenus ont été les suivants:

1. **La morphologie du foramen apical est à ce point variée qu'il est difficile d'exprimer sa taille précise en mesurant le diamètre du foramen. De ce fait il est préférable de déterminer sa dimension par une mesure de surface.**
2. **Un grand nombre de variations ont même été observées dans la dimension du foramen apical pour les dents du même type. Cependant, il a été aussi observé que le foramen est plus petit dans les dents de type petit et plus larges dans les dents de grand type. Il a été constaté également que dans les dents de même type, celles comptant un plus grand nombre de racines possèdent des foramen plus petits que ceux des dents dont les racines sont moins nombreuses.**

MOTS CLEFS:

Foramen apical - Méthode des répliques - Dimension de la région foraminale.

INTRODUCTION

A network of blood vessels and nerve fibers feeds the dental pulp, supplying it with oxygen and nutrients and controlling its metabolism. These blood vessels and nerve fibers enter and leave the tooth through the apical foramen. To the naked eye, the apical foramen appears as an extremely small dot or hollow, and even by histological examination, it does not seem quite large enough to admit passage into the pulp cavity of a bundle of blood vessels and nerve fibers. This, and the fact that degeneration or atrophy generally appears earlier and at a faster rate in dental pulp, occurring at about age thirty, than in other tissues and organs, make it desirable to accurately determine the size of the foramen.

The size of the apical foramen was, however, unknown until 1955, when Kuttler made measurements for the first time and reported his findings. Kuttler measured the diameter of the apical foramen using a micrometer and clarified that the apical foramen grows in size with increasing age according to the apposition of new layers of cementum, thus refuting the general notion at the time that the foramen contracted with age. Following Kuttler, Green (1958) also obtained measurements of the foramen diameter from observations using a stereoscopic microscope. In the present study, the area size of the apical foramen has been measures for anterior, bicuspid, and molar teeth using a «replica method» devised by the authors.

MATERIAL AND METHODS

The test materials used included 4,613 permanent teeth extracted from subjects of various ages. The ages, however, had not been recorded. Numbers for each type of tooth used are given in Table I. Only single-rooted samples of anterior teeth and lower bicuspids were used. The upper molars used were three-rooted. Upper bicuspids used were both single- and two-rooted, while the lower first molars used were two-, three- and four rooted, and lower second molars were two- and three-rooted. Furthermore, from an anatomical point of view, single-rooted teeth with two root canals were classified into teeth with two roots, and two-rooted teeth with three root canals were classified into those with three roots. Similarly, both two-rooted and three-rooted teeth with four root canals were grouped into those with four roots. For the sake of convenience, teeth having more apical foramens than the number of their canals were excluded from the study.

TABLE I.
Teeth used.
Dents utilisées.

Tooth	Number of teeth		Number of apical foramens	
Upper central incisor	259		259	
Lower central incisor	245		245	
Upper lateral incisor	235	1489	235	1489
Lower lateral incisor	275		275	
Upper canine	242		242	
Lower canine	233		233	
Upper 1st bicuspid	391		615	
Lower 1st bicuspid	231	1349	231	1797
Upper 2nd bicuspid	452		676	
Lower 2nd bicuspid	275		275	
Upper 1st molar	293		879	
Lower 1st molar	602	1775	1718	4928
Upper 2nd molar	294		882	
Lower 2nd molar	586		1449	
		4613		8214

The method for obtaining foraminal replica images and measurements was as follows: first, the teeth were placed in a 4% sodium hypochlorite solution in order to dissolve and remove the soft tissue surrounding the root, and then washed with water. Teeth with marked unevenness of cementum around the apical foramen were then ground, gently so as not to damage the foramen, with cuttlefish paper disks No. 236 to remove bumps and so facilitate preparation of the replica image of the foramen.

To obtain the replica images, acetylcellulose film was used, with methyl acetate as a solvent. The replica images were then photographed under twenty times magnification (Fig. 1). At the time of photographing, an objective micrometer was placed beside the replica image in order to provide a standard for measurement.

Film negatives so obtained were then used to produce photographs enlarged six times using an electron micrograph enlarger. A polar planimeter was then used with the enlarged photographs to determine the area of apical foramen. Here, each sample was measured three times and the area given as the arithmetic average. Then the foramen area size was converted into a circular area size and the diameter of this circle was obtained.

RESULTS

Table II shows the foramen area size measurements divided by tooth and root type.

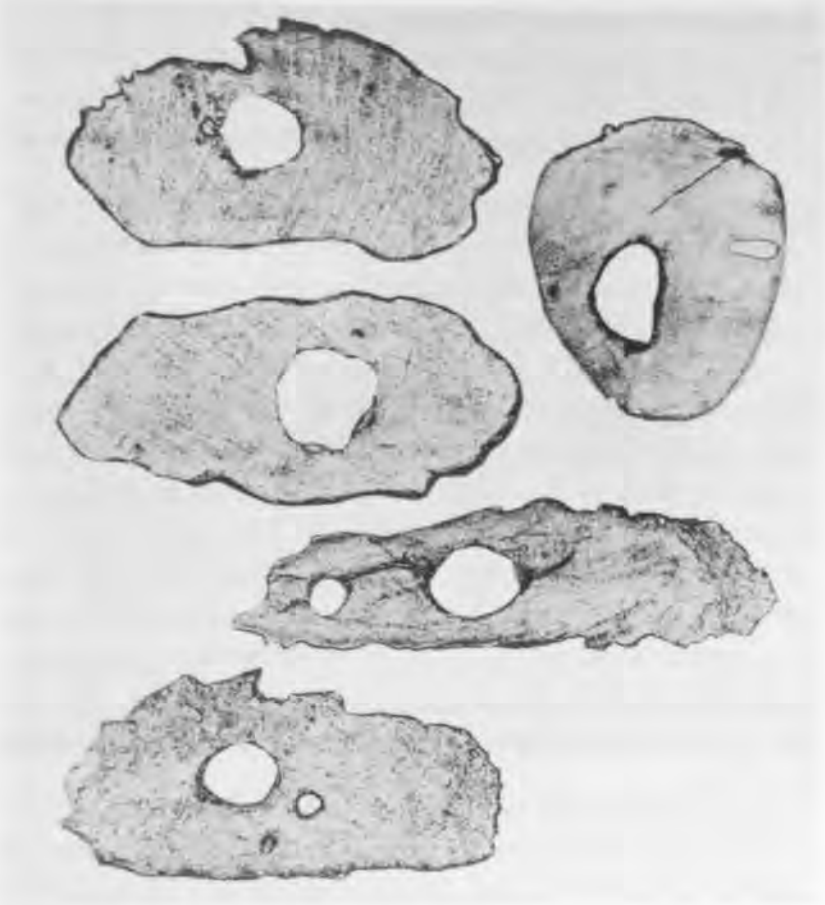

Fig. 1: Replica images taken of apical foramens.
Fig. 1: Images des repliques prises des foramen apicaux.

As for anterior teeth, the upper central incisors showed the largest apical foramen (160,000 μm^2), followed, in order, by upper and lower canines, upper and lower lateral incisors, and lower central incisors with the smallest value (95,000 μm^2).

The apical foramen in single-rooted upper first bicuspids was larger (175,000 μm^2) than that in lower first bicuspids. In two-rooted cases, however, apical foramens were small, measuring about 100,000 μm^2 in both lingual and buccal roots. A similar tendency was observed for second bicuspids.

Fig. 2 shows area size of the foramen in anterior teeth. The apical foramen appeared to be sligthly larger in upper than in lower teeth for each tooth type. In particular, the foramen of upper central incisors was twice as large as that of lower central incisors. Meanwhile, the foramen in the canines, both upper and lower, appeared large compared to those in other anterior teeth.

Fig. 3 is a graph showing the area sizes of apical foramens in bicuspids. Apical foramens were similar in size in first and second bicuspids. As with the anteriors, the size of the foramen in single-rooted upper bicuspids was larger than that in lower bicuspids. A comparison between single- and two-rooted upper bicuspids clearly shows that apical foramens in the latter are smaller. In two-rooted teeth, the foramen in the lingual and buccal roots was similar in size.

Figs. 4 and 5 show the areas of apical foramens in molars according to type of tooth and root.

TABLE II.
Area size of apical foramen ($\times 10^3$ μm^2).
Dimension de l'aire du foramen apical ($\times 10^3$ μm^2).

Tooth	Number of apical foramens	Mean ± S.E.M.
Upper central incisor	259	164.03 ± 6.89
Lower central incisor	245	95.08 ± 3.85
Upper lateral incisor	235	127.90 ± 4.40
Lower lateral incisor	275	108.32 ± 3.56
Upper canine	242	158.95 ± 6.71
Lower canine	233	146.02 ± 8.37
Upper 1st bicuspid		
Single-rooted	167	175.63 ± 8.88
Two-rooted		
Lingual root	224	99.04 ± 5.48
Buccal root	224	101.37 ± 5.38
Lower 1st bicuspid	231	119.16 ± 4.80
Upper 2nd bicuspid		
Single-rooted	228	176.81 ± 8.19
Two-rooted		
Lingual root	224	88.66 ± 5.16
Buccal root	224	96.73 ± 5.28
Lower 2nd bicuspid	275	143.19 ± 6.48
Upper 1st molar		
Three-rooted		
Mesiobuccal root	293	124.27 ± 6.03
Distobuccal root	293	123.21 ± 5.76
Palatal root	293	254.77 ± 12.12
Lower 1st molar		
Two-rooted		
Mesial root	201	178.80 ± 11.55
Distal root	201	231.40 ± 12.60
Three-rooted		
Mesiobuccal root	288	116.01 ± 5.55
Mesiolingual root	288	120.08 ± 6.75
Distal root	288	222.08 ± 9.07
Four-rooted		
Mesiobuccal root	113	146.95 ± 15.32
Mesiolingual root	113	119.38 ± 14.79
Distobuccal root	113	196.09 ± 18.80
Distolingual root	113	138.75 ± 12.89
Upper 2nd molar		
Three-rooted		
Mesiobuccal root	294	158.14 ± 7.88
Distobuccal root	294	117.98 ± 6.91
Palatal root	294	243.06 ± 10.34
Lower 2nd molar		
Two-rooted		
Mesial root	309	190.35 ± 9.15
Distal root	309	196.99 ± 7.20
Three-rooted		
Mesiobuccal root	277	102.37 ± 5.61
Mesiolingual root	277	101.70 ± 5.52
Distal root	277	172.28 ± 6.42

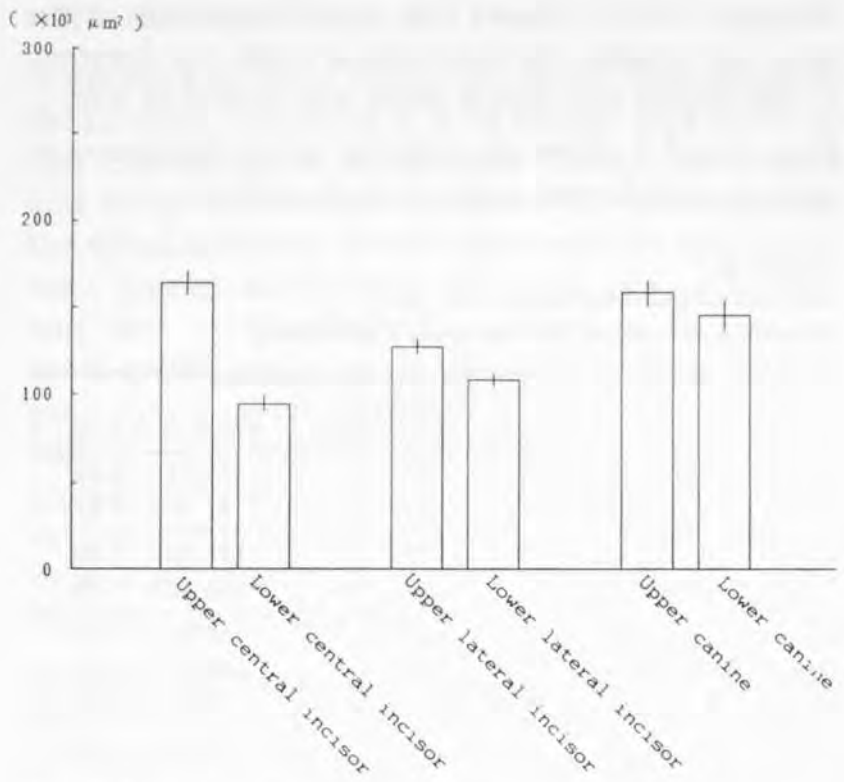

Fig. 2: Area size of apical foramen (anterior teeth).
Fig. 2: Dimension de l'aire du foramen apical (dents antérieures).

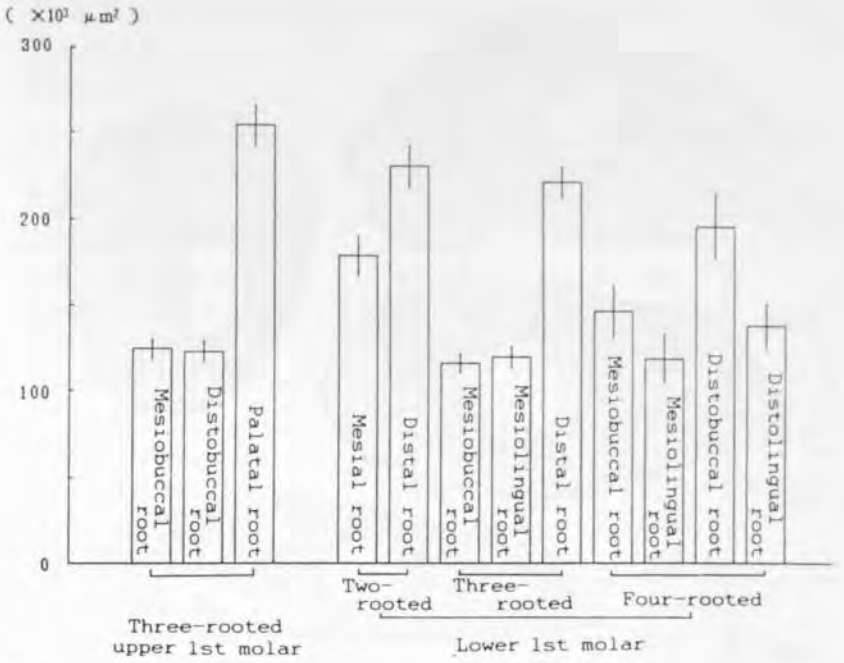

Fig. 4: Area size of apical foramen (1st molars).
Fig. 4: Dimension de l'aire du foramen apical (premières molaires).

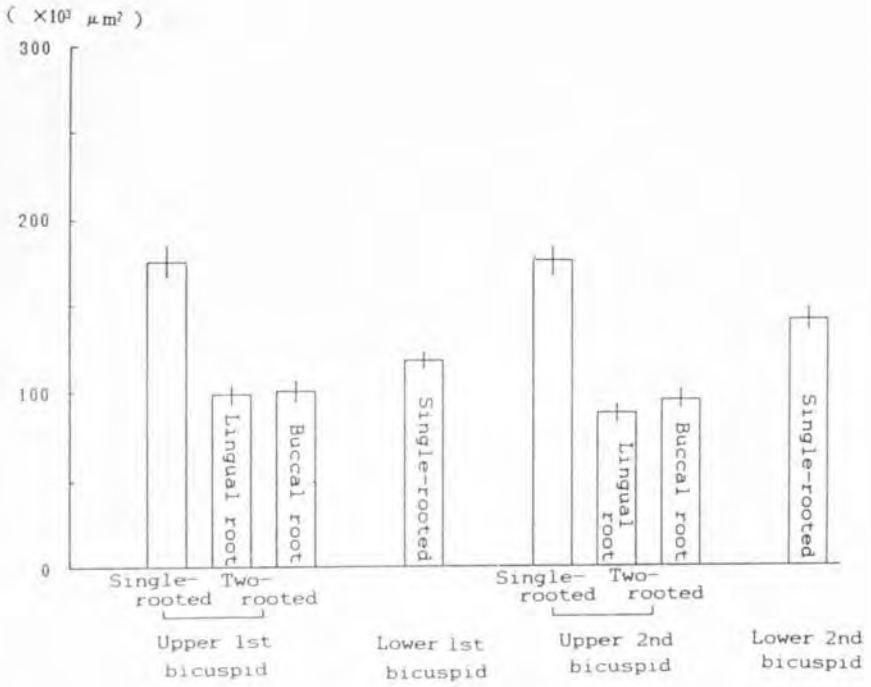

Fig. 3: Area size of apical foramen (bicuspids).
Fig. 3: Dimension de l'aire du foramen apical (bicuspides).

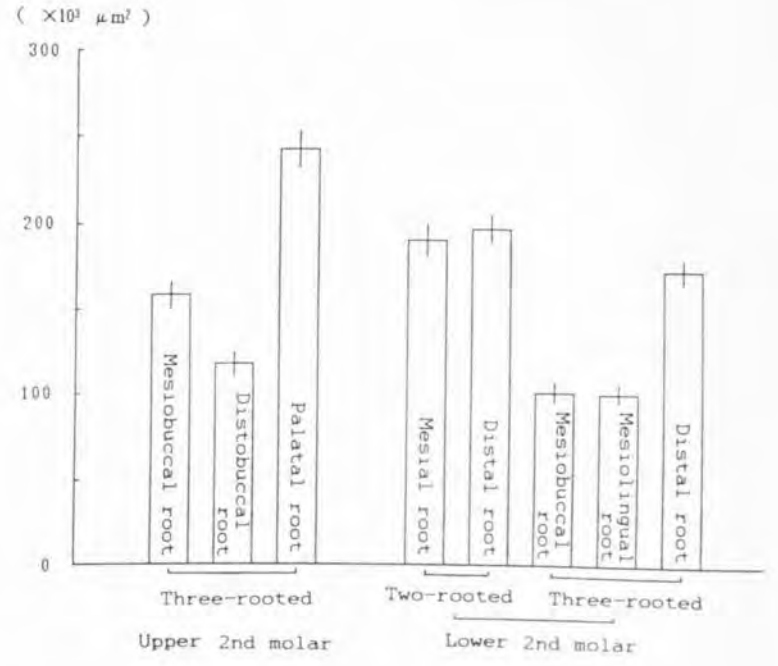

Fig. 5: Area size of apical foramen (2nd molars).
Fig. 5: Dimension de l'aire du foramen apical (secondes molaires).

In both upper first and second molars, the apical foramen of the palatal root was largest, lying between 24,000 μm^2 and 25,000 μm^2, while those of the mesio-buccal and disto-buccal roots were both small.

There was a tendency for foramens in lower molars to decrease in size when the number of roots increased. In two-rooted lower first molars, the apical foramen of the distal root (230,000 μm^2) was larger than that of the mesial root (180,000 μm^2), and in three-rooted lower first molars, the foramen of the distal root was 220,000 μm^2, or approximately the same size as those in two-rooted lower first molars. In lower first molars whose mesial root bifurcated into mesio-buccal and mesio-lingual roots, however, apical foramens in both these roots were small. In four-rooted lower first molars, the apical foramen of the disto-buccal root appeared to be slightly larger than foramens in the other three roots.

The area size of apical foramens in second molars, as shown in Fig. 5, indicate that, as with upper first molars, the foramen of the palatal root in upper second molars is largest (24,000 μm^2), and that the foramens of the mesio-buccal and disto-buccal roots are small. In lower second molars, apical foramens have sizes comparable to those in two- and three-rooted lower first molars. In two-rooted lower second molars, the foramens of their mesial and distal roots are large, while in three-rooted lower second molars, the mesial root bifurcates into mesio-buccal and mesio-lingual roots, both of which have small apical foramens.

Fig. 6 is a graphical comparison of the area size of the apical foramen in different types of teeth. The values given are values of area per tooth, including multiple-rooted teeth. In the case of multiple-rooted teeth, the mean value obtained from the total amount of their foraminal area is given.

In each type of tooth, uppers seem to have larger foramens than lowers.

Among the uppers, the molars have markedly large apical foramens (500,000 μm^2 per tooth). Compared to these, foramen area sizes of other teeth are far smaller, followed in order by the bicuspids, central incisors, canines and lateral incisors.

As in the upper molars, there were shown particularly large apical foramens in the lowers, with 470,000 μm^2 for lower first molars and 390,000 μm^2 for lower second molars. Moreover as in the uppers, the apical foramens in the other types of lowers are far smaller in size compared to the lower molars.

Meanwhile, two differences can be noted between the uppers and lowers: in the latter, the foramen in canines is larger than that in bicuspids, and the smallest foramen is found in central incisors.

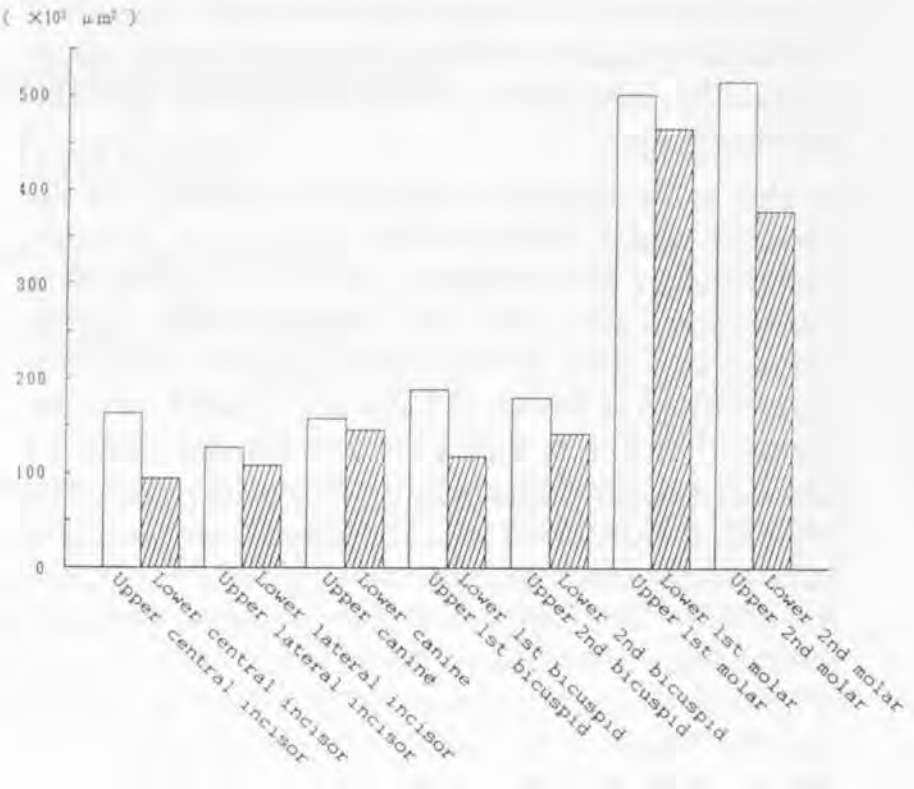

Fig. 6: Area size of apical foramen (apical area per tooth).
Fig. 6: Dimension de l'aire du foramen apical (aire apicale par dent).

DISCUSSION

It was not untill Kuttler's study in 1955 that data became available on the diameter of the apical foramen. Following Kuttler, Green (1958) also reported diameter measurements of the foramen.

The foramen morphology which is rich in variety, however, was ignored in the methods used by Kuttler and Green in their diameter determinations, so that their measurements may not be an accurate reflection of real values.

The method of measurement adopted by the present authors makes use of a replica method that allows the preparation of clear replica images of the foramen, and because of this, the area measurements obtained from these replica images by means of a planimeter may be considered to be accurate values of area for the apical foramen. By using the area values obtained of the foramen, moreover, it is possible to obtain values of foraminal diameter.

Based on his studies, Kuttler (1955) reported that the cementum which forms the apical foramen also forms the cementum canal, and that this canal opens up in funnel fashion toward the foraminal opening.

He furthermore stated that owing to the addition of new layers of cementum upon the cementum forming the foramen, the foraminal opening migrates to the outer surface of each new layer of cementum surrounding the cementum opening, and that as a result the diameter of the foramen increases with age. Kuttler then went on to state that his study disproved textbook accounts of dental pulp tissue being strangulated by contraction of the apical foramen with increasing age.

In this study, Kuttler used for the diameter of the foramen values averaged from eight types of teeth, and therefore his results can not be compared with our foramen area sizes. For comparison we converted our area sizes into foraminal diameters for each type of tooth as shown in Table III. Green's measurements of lower molars gave average diameters of 520 μm for the foramen in the mesial root, and 640 μm in the distal root. The present authors have obtained the following diameter values: 477 μm and 492 μm for the mesial roots of the lower first and second molars, respectively; and 543 μm and 501 μm for the distal roots of the lower first and second molars, respectively. Green's values are therefore seen to be larger than those of the present study both for mesial and for distal roots. While this discrepancy may in part be due to racial differences in the sizes of apical foramen, the present authors believe that it stems more from a difference in method of measurement.

The measurements obtained by the present authors indicate that apical foramens are small in smaller teeth, that is, in the lower central incisors and in upper and lower lateral incisors, and large in the larger teeth, that is, in upper and lower molars. This suggests that there is a close connection between the size of a tooth and that of its apical foramen.

In upper bicuspids, foramens were smaller in two-rooted than in single-rooted teeth, while in lower molars, the apical foramens in three- and four-rooted teeth were smaller than those in two-rooted teeth. It was noted, in other words, that for teeth of the same type these exists a tendency for the apical foramen to decrease in size with increase in number of dental roots.

TABLE III.
Diameter size of apical foramen (μm).
Diamètre du framen apical (μm).

Tooth	Number of apical foramens	Mean
Upper central incisor	259	457
Lower central incisor	245	348
Upper lateral incisor	235	404
Lower lateral incisor	275	371
Upper canine	242	450
Lower canine	233	431
Upper 1st bicuspid		
Single-rooted	167	473
Two-rooted		
Lingual root	224	355
Buccal root	224	359
Lower 1st bicuspid	231	390
Upper 2nd bicuspid		
Single-rooted	228	474
Two-rooted		
Lingual root	224	336
Buccal root	224	351
Lower 2nd bicuspid	275	427
Upper 1st molar		
Three-rooted		
Mesiobuccal root	293	398
Distobuccal root	293	396
Palatal root	293	570
Lower 1st molar		
Two-rooted		
Mesial root	201	477
Distal root	201	543
Three-rooted		
Mesiobuccal root	288	384
Mesiolingual root	288	391
Distal root	288	532
Four-rooted		
Mesiobuccal root	113	433
Mesiolingual root	113	390
Distobuccal root	113	500
Distolingual root	113	420
Upper 2nd molar		
Three-rooted		
Mesiobuccal root	294	449
Distobuccal root	294	388
Palatal root	294	556
Lower 2nd molar		
Two-rooted		
Mesial root	309	492
Distal root	309	501
Three-rooted		
Mesiobuccal root	277	361
Mesiolingual root	277	360
Distal root	277	468

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