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ROOT SURFACE MEASUREMENT AND A METHOD FOR X-RAY DETERMINATION OF ROOT SURFACE AREA

by

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The area of the root surface of human teeth has interested several investigators. Attempts have been made, both to establish a connection between masticatory pressure and periodontal membrane area and to find how great a loss in attachment area will be caused by a given horizontal bone loss. With such purposes in view, average values for the surface area of the various teeth have been calculated. Thus *Morelli* (1920) gives a series of area values based on the root as a well-defined geometric figure — the central incisor in the upper jaw, for instance, being considered a cone — the surface area of which can be calculated with the aid of a simple mathematical formula.

Brown (1950) describes a method of root surface measurement employing the so-called membrane technique. The root of the tooth is coated with a latex solution, which, after setting, is pulled off as a membrane. This membrane is then laid on graph paper and the number of covered millimetre squares counted. *Boyd* (1958) measured the area of teeth belonging to the following categories: molars, premolars, canines, lateral incisors and central incisors, using the membrane technique.

The mean value of 5 teeth from each category was correlated with the masticatory pressure, exerted by these teeth. Moreover, the root surface area was compared to the whole of the denture

bearing area, corresponding to and including the sites, where the teeth were placed before extraction. *Tylman & Tylman* (1960) give values for the periodontal area in the entire dentition and compare this to the masticatory pressure. How these values were arrived at and how many teeth were measured, is not stated.

The work presented here is an attempt to establish whether it is possible with resonable certainty to state average values for the root surface area of human teeth and to investigate whether one can determine the root surface area of a given tooth by X-ray methods.

MATERIAL

For measurement, 238 extracted teeth were used. Their distribution is recorded in Table II. Each tooth had to fulfil the following conditions:

1) The root should be fully developed and intact.
2) The identity of the tooth should be unambiguous.
3) The cemento-enamel junction should be intact and determinable with certainty.
4) The root should not deviate from the "normal" with reference to shape, and there should not be demonstrable macroscopic pathological changes (fusion of roots, marked hypercementoses, etc.).

METHOD

The measurements were made using the membrane technique. The following procedure was adopted:

1) The cemento-enamel junction is marked with a sharp pencil. In doubtful cases this is carried out under a dissection microscope.
2) The root is coated with a solution consisting of 10 g polyvinyl chloride (PVC) in 6 g dibutyl phthalate, with 1.5 g echt rot*) added to make the membrane impervious to light (Fig. 1a & b).
3) The tooth is placed in a thermostat and the membrane polymerized for 30 mins. at 130° C. A longer polymerization time

*) obtained from I. G. Farben, Germany.

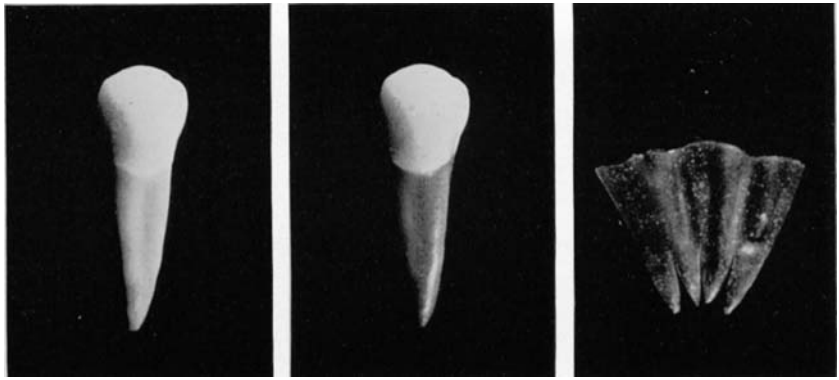

Fig. 1. a and b show the tooth before and after painting with P.V.C. solution. c shows the peeled off P.V.C. membrane.

than 30 mins. causes the film to become brittle, while a shorter time makes it too weak.

4) The tooth is cooled slowly. The membrane, which has a thickness of 100—200 μ, is slit up along a line from the cemento-enamel junction to the apex, after which it is loosened and peeled off. In the case of multi-rooted teeth the film is removed in two or three pieces according to the number of roots (Fig. 1c).
5) Sufficient cuts are made in the film to permit it to be placed without folds between two slides which are pressed closely together with clips.
6) In the darkroom, the membrane is placed on a photographic film which is then exposed. After development, the film is placed in an enlarger set to exactly 5$\times$linear enlargement.
7) The enlarged image of the figure is projected onto drawing-paper and the outline of the membrane drawn.
8) The area of the figure is measured with a planimeter (type AMSLER) and the resultant value divided by 25 (square of the linear enlargement). This gives the surface area of the root in sq. mm. All planimeter measurements are made twice. In the present study the difference between the two measurements is less than 3 per thousand in all cases.

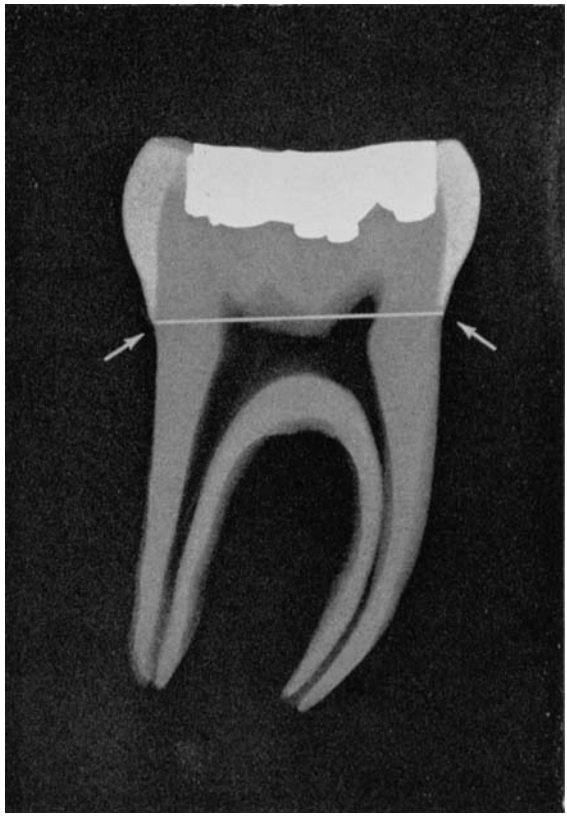

Fig. 2. Crown-root demarcation as applied in measurements.

9) Finally, the X-ray photograph is taken. With the help of adhesive tape the teeth are placed on an X-ray film in such a position that exposure as nearly as possible corresponds to an intraoral, isometric, orthoradial exposure with a long cone. The exposed film is enlarged as before, the 5×linear image drawn in without that of the crown. The junction between the crown and the root is drawn as a straight line between the two most apical points of the enamel shadow, mesially and distally (Fig. 2). The root-shadow drawing thus produced is measured as described above.

The accuracy of the method

To check the accuracy of the method, the procedure described above was used on a cylindrical test body with a known surface area. The discrepancy between the measured and true values was less than 1 %. Furthermore, in two cases, two and three measurements respectively were made of the same tooth and the greatest deviation from the average was in both cases equal to or less than 1.2 % (Table I).

To check the accuracy of the X-ray method 10 X-ray photographs were taken of the same tooth. Measurements showed the greatest deviation from the average to be 0.7 %.

Possible small inaccuracies due to smoothing of nonplane parts of the P.V.C. membrane are undeterminable and assumed to be negligible.

Table I.

Results of the control measurements.

Object	known area sq. mm	measurement I sq. mm	measurement II sq. mm	measurement III sq. mm	greatest deviation
test body	238.048	237.2	235.6		1.0 %
tooth no. 21		223.8	224.4		0.3 %
„ „ 103		212.4	215.2	217.3	1.2 %

RESULTS

The average area for each group of teeth is given in Table II, column 1. As an expression of variation from the average, the standard deviation is stated in column 2. A comparison between the average and the standard deviation shows that the latter varies in proportion to the former. This is also apparent from the calculated relative standard deviations or coefficients of variation in column 3, which vary at random around a calculated value of just under 15 %. This means that the relative variation is the same for all types of teeth, and that deviations of up to 30 % of the average values can be expected to occur quite frequently.

Table II

Results of measurement of root surface areas.

Type of tooth	1 average area sq.mm	2*) standard deviation	3 coefficient of variation	4 no. of measurements	5 relative sizes	6 *Tylman & Tylman* (1960)	7 *Boyd* (1958)
Sup.							
I^1	204	31.4	15.4	19	6	139	204.5
I^2	179	24.9	13.9	25	7	112	177.3
C	273	43.9	16.1	26	3	204	266.5
P^1	234	33.7	14.4	20	4	149	219.7
P^2	220	39.0	17.7	19	5	140	216.7
M^1	433	40.9	9.4	15	1	335	454.8
M^2	431	62.5	14.5	10	2	272	416.9
Inf.							
I_1	154	26.5	17.2	10	7	103	162.2
I_2	168	21.5	12.8	10	6	124	174.8
C	268	42.2	15.7	18	3	159	272.2
P_1	180	27.2	15.1	24	5	130	196.9
P_2	207	26.6	12.9	17	4	135	204.3
M_1	431	59.5	13.8	15	1	352	450.3
M_2	426	69.7	16.4	10	2	282	399.7

*) calculated from the formula $s_y = \sqrt{\frac{\sum (y - \bar{y})^2}{n - 1}}$,

where y is the area found by membrane measurement, $\bar{y}$ the group average as entered in column 1, and n the number of measurements in the group.

The application of X-ray photography

If without direct measurement a more accurate value than those in Table II is required for the root surface area of a given tooth, the X-ray method may be used. To illustrate the relationship between X-ray area and actual root surface area, two of the regression estimates mentioned below are recorded graphically in Fig. 3. By the method of least squares, calculation of the constants in the regression function $\ddot{y} = a + bx$, where $\ddot{y}$ denotes the calculated surface area and x the X-ray measurement, is

made for each group. These estimates are presented in Table III, where the standard deviation showing the variation about the empirical regression line is also indicated. In the last column the 95 % confidence interval is given for each group.

Table III.

Direct area measurements correlated with X-ray measurements.

Type of tooth	empirical regression line	standard deviation*)	95 % confidence interval
Sup.			
I^1	$\ddot{y} = 61+2.3x$	10.1	$y \pm 21$
I^2	$= 53+2.5x$	13.0	± 27
C	$= 74+3.0x$	17.9	± 37
P^1	$= 70+3.4x$	18.7	± 39
P^2	$= 12+4.4x$	16.4	± 35
M^1	$=165+3.2x$	27.7	± 60
M^2	$=123+3.6x$	32.8	± 76
Inf.			
I_1	$= 26+3.5x$	9.0	± 21
I_2	$= 49+3.0x$	7.0	± 16
C	$=-6+3.8x$	16.8	± 36
P_1	$= 6+3.6x$	9.9	± 21
P_2	$= 59+2.6x$	13.9	± 30
M_1	$=111+3.3x$	24.7	± 53
M_2	$= 50+3.9x$	17.9	± 41

*) calculated from the formula $s_{y \cdot x} = \sqrt{\frac{\sum (y - \ddot{y})^2}{n - 2}}$,

where $\ddot{y}$ denotes the calculated root surface, y the observed value and n the number of measurements in the group.

Examples:

The root surface area of a given central incisor in the upper jaw is to be found: An X-ray photograph has been taken as described above and after planimetry it has been found that $x = 60$. The root surface area is thus $\ddot{y} = 61 + 2.3 \cdot 60 = 199$

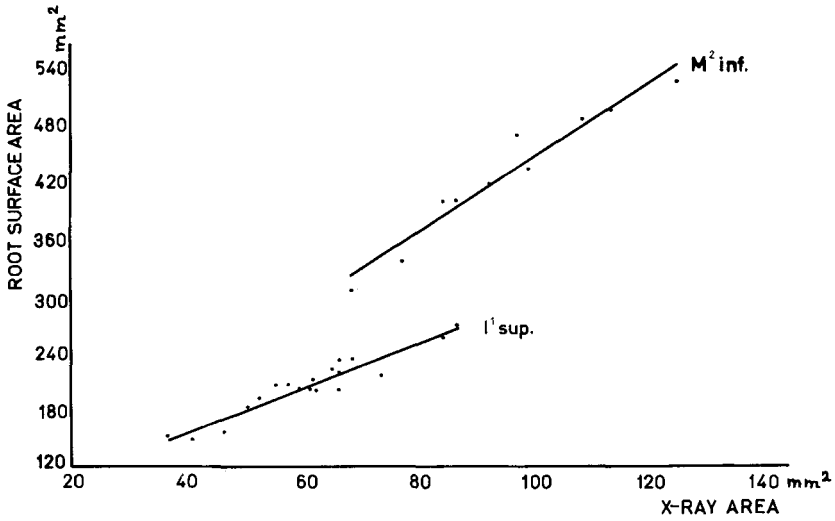

Fig. 3. The graph illustrates the relationship between X-ray area and actual root surface area.

sq. mm; 95 % confidence interval: 199 ± 21 sq. mm, *i.e.* an accuracy of about ± 10 %.

The root surface of a second mandibular molar: Observed X-ray value x = 114; the estimate is thus $\ddot{y} = 50 + 3.9 \cdot 114 = 445$ sq. mm; 95 % confidence interval: 445 ± 41 sq. mm, *i.e.* the accuracy here is also about ± 10 %.

DISCUSSION

Measurement of the root surface area of 238 extracted teeth shows that the bulk of the values in each group of teeth is scattered around the average with a +/— 30 % limit. A comparison between the values in Table II, columns 1, 6 & 7, shows that *Boyd's* and the present author's figures are 25—55 % higher than those of *Tylman & Tylman*. It should be noted that the latter expressly point out that their values can only be used as a basis of comparison. By this is apparently meant that the stated area measurement is not an expression of the true size of the root surface area, and that the figures will not be usable where

an exact knowledge of the root surface area of a given tooth or group of teeth is required.

The values arrived at by *Boyd* (1958) are almost identical with those presented here. The reason for the small differences may be that *Boyd's* groups are quite small — only 5 teeth of each type measured — so that a single extreme value will influence the average considerably. *Boyd* made his measurements with the aid of a lead film, but there is no information as to how its area was arrived at.

In Table II, column 5, the groups are numbered according to the relative size of the average surface area. As one would expect, the 1st molars in both upper and lower jaws have the largest root surface areas, while the lateral incisor in the upper jaw and the central incisor in the lower jaw show the lowest values. The order found is identical with that of *Tylman & Tylman*. It should be noted that 3rd molars are not included in the investigation, partly because the range of values for the root surface area is extremely wide, so that an average figure would have no significance, and partly because the morphological variations are so numerous, that the X-ray method cannot be used.

In investigations where root surface areas are to be employed, it will frequently be unsatisfactory to employ the average values on account of the wide range, but, as shown, the X-ray photographic method described will reduce the uncertainty to about one half to one third, dependent on the group and size of tooth.

In determination of X-ray shadow area, planimetry is used in preference to the method described by *Brown* (1950) of counting the squares on graph paper. The latter method is considered to involve a good deal of uncertainty, as fractions of a square have to be estimated along the whole outline of the figure.

A method which does not require a planimeter is described by *Knudsen* (1958) who, in determining the area of brain ventricles, made use of the so-called weighing method, which can be directly applied to determine root surface areas. The 5×enlarged drawing of the root shadow is cut out accurately and weighed on a balance (sensitivity 0.1 mg). From the same sheet of card, pieces of known area are cut out and weighed, and the area of the figure calculated from this. To exclude errors stemming from different thickness of sheets, a new standard is calculated for

each sheet used. The method takes somewhat longer to use and is hardly as accurate as direct area measurement with a planimeter.

Finally, it should be noted that in the present work the X-ray photographic method has not been tested clinically. In both periodontology and prosthetics there exists a need for a suitable method of measurement of the root membrane area of a given tooth or group of teeth. It is assumed that the X-ray photographic method here described, will be applicable in clinical work if the isometric exposure requirements mentioned are fulfilled.

CONCLUSIONS

The present study demonstrates that area determination of root surfaces can be easily and accurately made with the aid of a polyvinyl membrane technique.

In planimetry of PVC membranes from 238 teeth, it has been found that the bulk of the values in each group of teeth is scattered around the average with a +/— 30 % limit.

Investigations using an X-ray photographic method devised for the purpose have established that determination of root surface areas can be made with a margin of error of about 10—15 %.

SUMMARY

A method is described for measurement of the root surface area of human teeth and average values for all the permanent teeth, except the 3rd molar, are given (Table II, column 1). These measurements show that the coefficient of variation is about 15 %, *i.e.* a 30 % deviation from the average values will occur quite frequently.

In addition, a method is described by which, with the aid of an X-ray photograph and measurement of this image, one is able to determine the root surface area of a given tooth with an accuracy of about ± 10—15 % (Table III).

The X-ray photographic method has been developed on extracted teeth and the results have not been checked clinically. It is assumed, however, that the method can be applied *in vivo*.

Acknowledgement

The author wish to thank Mr. *L. Pank Pedersen,* Institute of Statistics, University of Århus, for performing the statistical part of the present work.

RÉSUMÉ

MESURE DE LA SURFACE DES RACINES ET UNE MÉTHODE RADIOGRAPHIQUE POUR DÉTERMINER LES SURFACES DES RACINES

Une méthode pour mesurer les surfaces des racines des dents humaines est décrite, et les valeurs moyennes sont indiquées pour toutes les dents de la denture, à l'exception pourtant des 3èmes molaires (tableau 2, colonne 1). Ces mesures montrent que le coefficient de variation est d'environ 15 %, c'est-à-dire qu'un écart de 30 % par rapport aux moyennes se produire assez souvent.

De plus est décrite une méthode permettant de déterminer, à l'aide d'une radiographie et de mesures faites sur celle-ci, la surface de la racine d'une dent donnée avec une précision d'environ +/— 10—15 % (tableau 3).

La méthode par radiographie a été développée sur des dents extraites, et les résultats n'ont pas été contrôlés au point de vue clinique. Il est à présumer, cependant, que la méthode décrite pourra être appliquée sur des patients.

ZUSAMMENFASSUNG

WURZELOBERFLÄCHENMESSUNG UND EINE METHODE ZUR BESTIMMUNG DES WURZELOBERFLÄCHENAREALS MITTELS RÖNTGENAUFNAHMEN

Es wird eine Methode zur Messung des Wurzeloberflächengebietes der menschlichen Zähne angegeben. Der Mittelwert aller Zähne ausser dem 3. Molaren wird gezeigt (Tafel II, Spalte 1). Diese Messungen zeigen, dass der Schwankungskoeffizient um 15 % liegt, d. h. eine 30 %-ige Abweichung vom Durchschnittswert wird recht häufig vorkommen.

Als Zusatz wird eine Methode beschrieben, bei welcher man mittels Röntgenaufnahmen und Ausmessung derselben in der Lage ist, das Wurzeloberflächengebiet eines gegebenen Zahnes

mit einer Genauigkeit von etwa +/— 10—15 % zu bestimmen (Tafel III).

Die Röntgenphotomethode wurde an extrahierten Zähnen entwickelt, und die Ergebnisse wurden nicht klinisch überprüft. Es wird aber vermutet, dass diese Methode an Patienten angewandt werden kann.

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