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# The length of teeth

## A statistical analysis of the differences in length of human teeth for radiologic purposes

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Intraoral radiograms can be made according to the long tube paralleling technique utilizing aiming devices. An important factor in the design of these instruments is the length of the teeth to be radiographed. Reliable data regarding the length of the teeth in the different regions of the mouth are not available. Information on the length of teeth was therefore collected by measuring 1,400 extracted teeth. A statistical analysis of the data finally resulted for each region of the mouth and for both sexes in a length value which could be used for the design of the aiming devices.

**I**ntraoral radiograms made with the long tube paralleling technique can be obtained using aiming devices which indicate extraorally the desired position of the X-ray machine. A factor influencing the design of these aiming devices is the length of the tooth to be radiographed.<sup>1</sup> A well-founded design of the instruments therefore requires accurate information, among others, on the mean values and standard deviations of the length of the teeth in the different regions of the mouth. In making a full-mouth radiographic survey, the following regions can be distinguished: incisor area, cuspid area, premolar area, and molar area.

An important requirement for the correct interpretation of the condition of the teeth and their direct surrounding structures on a periapical radiogram is the presence of sufficient space between the apices of the teeth and the border of the mounted film. This space should not be less than 3 mm. In order to meet this requirement even in patients with extremely long teeth, the design of the aiming devices should be based on the maximum length of the teeth found in each region to be radiographed. This, however, would cause an unfavorable direction of the X-ray beam when making radiograms of the shorter teeth. Therefore, in each region, the maximum length found after excluding 5 percent of extremes was chosen as the relevant length

for the design of the aiming devices. Values for the mean length of the teeth can be found in the literature (Table I).<sup>2-21</sup> A striking similarity can be observed between the figures of some of the authors. There is a lack of information regarding the numbers of teeth investigated, the way of measuring, and the standard deviation of the values.

Although it has been demonstrated that a distinct sex difference exists for several tooth dimensions,<sup>13, 14, 22, 23</sup> a statistical proof of the existence of such a difference in the length of the teeth is not available.

From the foregoing, it was concluded that the following questions are either interesting from the standpoint of dental anatomy or important for the design of the aiming devices:

1. What is the mean, the standard deviation, the minimum, the maximum, and the range of the length of the different types of maxillary and mandibular teeth in males and females (the third molar was excluded), and what is the distribution of the length of these different groups of tooth types?

2. Is there a statistical difference in tooth length between the sexes?

3. Is there a statistically significant difference in length between the first and the second incisors originating from one individual and from one quadrant of the mouth? The same can be questioned concerning the differences between the first and the second premolars and between the first and the second molars. These data are important, because in making a full-mouth radiographic survey, the compared teeth are depicted on the same radiogram.

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**Table I.** Mean length of human teeth

Author	Racial group and sex	Number (n)	Length of maxillary teeth (mm.)								Number (n)
			1	2	3	4	5	6	7	8	
Aprile-Figun			22.5	22.0	26.8	21.0	21.5	22.0	20.7	18.0	
Bjorndal and associates	Caucasians (men)	36-51	23.7	23.1	27.3	22.3	22.3	22.3	22.2	..	8-60
Black	White		22.5	22.0	26.5	20.6	21.5	20.8	20.0	17.1	
Broomell and Fischelis*			22.35	21.59	26.67	20.32	21.33	20.57	20.06	17.27	
Bouland and Lebourg			22.0	22.0	26.0	21.0	22.0	22.0	21.0	18.0	
Campbell	Australia		24.5	24.5	27.5	22.6	22.3	19.5	19.6	19.7	
Dewey			22.5	22.0	26.5	20.6	21.5	20.8	20.0	17.1	
Dieulafé and Herpin			21.0	21.0	26.0	21.0	23.0	20.0	21.0	18.0	
Drennan	Bushmen	10-20	21.8	20.4	24.2	21.1	21.1	17.6	18.4	18.0	20-27
Kraus and associates			23.5	22.0	27.0	23.5	22.5	19.5	18.0	17.5	
Marseillier			22.5	22.0	26.5	21.0	21.0	22.3	20.7	18.0	
Mörike and associates			24.0	22.5	27.0	21.7	21.5	21.3	21.1	-	
Moorrees		1-8	20.6	21.3	-	20.3	20.0	19.6	-	17.4	2-4
Mühlreiter			24.0	22.5	27.0	21.7	21.5	21.3	21.1	-	
Pucci and Reig			21.8	18.5	26.4	21.8	21.6	21.3	21.7	-	
Sauvez and associates			22.0	21.8	26.8	20.7	21.5	20.7	20.2	-	
Shaw	Bantu	62-91	23.9	23.0	27.2	21.8	22.3	20.0	19.0	17.5	62
Sicher and Tandler	(men)	(1)	24.0	22.5	27.0	21.7	21.5	21.3	21.1	-	
Wheeler			23.5	22.0	27.0	22.5	22.5	20.0	18.5	17.0	

\* The original values of Broomell and Fischelis are given in inches

**Table II.** Length of maxillary teeth

Tooth (n = 50)	Men					Women				
	Mean length	S.D.	Minimum length	Maximum length	Range	Mean length	S.D.	Minimum length	Maximum length	Range
1	25.2	1.74	22.0	28.5	6.5	23.8	1.71	19.5	26.5	7.0
2	23.6	2.21	17.5	29.5	12.0	22.5	1.55	18.5	26.0	7.5
3	29.1	2.24	24.5	36.0	11.5	25.8	2.61	20.0	32.5	12.5
4	22.5	1.72	18.5	26.5	8.0	21.4	1.67	18.5	24.0	5.5
	22.6*	1.71	18.5	26.0	7.5	21.8*	1.69	18.5	24.5	6.0
5	22.6	1.76	18.5	27.0	8.5	21.0	1.84	17.5	25.0	7.5
	22.6*	1.92	18.5	28.0	9.5	21.3*	1.95	17.0	25.5	8.5
6	21.9	1.84	17.5	25.0	7.5	21.1	1.17	19.0	23.0	4.0
	23.7*	1.87	20.0	27.0	7.0	22.8*	1.42	19.5	26.0	6.5
7	21.5	2.11	16.0	26.0	10.0	20.8	1.65	16.0	23.5	7.5
	23.1*	2.23	16.5	27.5	11.0	21.9*	1.73	16.5	25.5	9.0

\* Lengths given in mm. For upper premolars and molars the second figure (\*) is the distance from the top of the buccal cusps to the apex of the (palatal) root measured diagonally.

4. Is there a positive correlation between the length of the pairs of teeth mentioned in No. 3? In other words, when the first incisor of one person is longer than the same tooth of another person, does this also hold true for the second incisor?

5. What is the length of the teeth, for the different regions of the mouth, on which the design of the aiming devices can be based? The maximum length after excluding 5 percent of extremes was chosen for each region as the starting point. This length value is called the radiographic relevant length (r.r.l.).

**MATERIALS AND METHODS**

The material used for this study consisted of teeth extracted from patients in the central part of The Netherlands. The teeth were collected by dentists in their private practice and by dentists working in clinics of the National Health Service, military service, and a dental school. The teeth of men and women were collected separately. No special measures were taken to select certain age or racial groups.<sup>13, 14, 18, 22, 24</sup>

Fifty specimens of each tooth type were studied, giving a total of 50 × 7 (tooth type) × 2 (maxilla and

Length of mandibular teeth (mm.)							
1	2	3	4	5	6	7	8
20.7	22.1	25.6	22.4	23.0	21.0	19.8	17.0
21.8	23.3	26.0	22.9	22.3	22.0	21.7	-
20.7	21.1	25.6	21.6	22.3	21.0	19.8	18.5
20.57	21.59	25.4	21.33	22.09	20.82	19.55	15.74
20.0	22.0	25.0	22.0	23.0	21.0	20.0	17.0
21.0	24.5	28.0	22.6	22.5	21.9	22.2	19.0
20.7	21.1	25.6	21.6	22.3	21.0	19.8	18.5
19.0	22.0	24.0	22.0	21.0	20.0	20.0	17.0
18.8	20.5	23.6	20.3	20.7	17.4	18.7	17.6
21.5	23.5	26.0	22.5	22.5	21.5	20.0	18.0
20.7	22.1	25.6	23.0	23.5	21.0	19.8	17.0
21.4	23.2	25.4	21.6	23.2	21.0	19.8	18.5
16.2	18.8	-	20.8	20.4	20.4	-	-
21.4	23.2	25.4	22.8	23.2	22.8	22.0	-
20.8	22.6	25.0	21.9	22.3	21.9	22.4	-
20.6	22.3	25.6	21.8	22.3	20.9	19.8	-
20.2	21.6	27.9	22.7	22.4	20.5	20.0	18.5
21.4	23.2	25.4	18.5	23.2	22.8	22.8	-
			27.0				
21.5	23.5	27.0	22.5	22.5	21.5	20.0	18.0

mandible) × 2 (males and females) = 1,400 teeth.

The cuspids were collected separately. The incisors, the premolars, and the molars were collected in pairs, which means that only two incisors, two premolars, or the first and second molars extracted from one quadrant and from one patient were considered.

For the collection of the specimens, the dentists were provided with plastic bags divided into two compartments indicated by the numbers 1 and 2 for the first and the second teeth of the pair.

Only completely developed teeth which could be measured in full length were considered. A cavity or restoration in the teeth caused no objection, provided that it was not present at a place important for the measurement.

The abrasion of the teeth selected for measuring had to be minimal.<sup>25, 26</sup> To compensate for the abrasion still present, the measurements of all premolars and molars were rounded off upward to the nearest half or whole millimeter.

The original length of the incisors and cuspids was determined from radiograms of these teeth. The teeth were placed with their long axis parallel to the film. The use of a nearly parallel X-ray beam (large focal spot-to-object distance), directed perpendicular to the film, resulted in an image of the teeth with their true length. On these radiograms, the part of the crowns lost due to abrasion was reconstructed, after which the total length of the teeth was measured. All these mea-

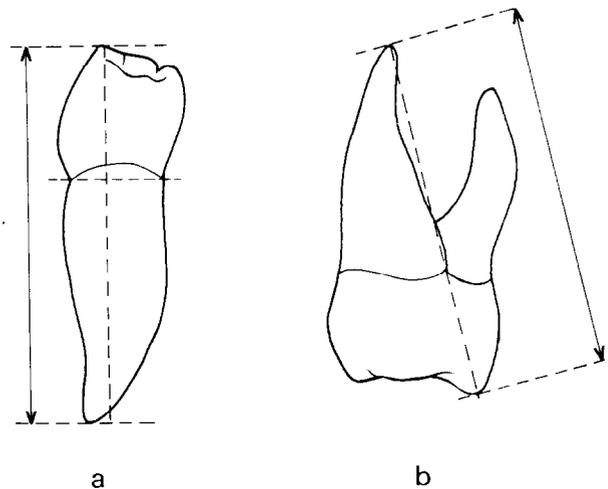


Fig. 1. a, The length of a tooth measured perpendicular to the connecting line of the buccal and palatal cervical border of the crown. b, The length of a tooth measured diagonally.

surements were rounded off to the nearest half or whole millimeter.

The measurements were carried out with a tested vernier caliper which had an error of less than 0.01 mm. The length of a tooth was defined as the distance, measured perpendicular to the connecting line of the buccal and palatal cervical border of the crown, from the top of the highest cusp to the apex of the longest root (see Fig. 1, a).

As the data were especially collected for radiographic purposes, the dimension of the premolars and molars, producing the "total length" of the image on the film, was also measured. For this purpose, the distance from the top of the buccal cusps to the apex of the longest (palatal) root was measured diagonally (see Fig. 1, b).

## RESULTS AND CONCLUSIONS

1. Table II presents the mean, standard deviation (S.D.), minimum, maximum, and range of the length of the different types of maxillary teeth of both sexes.

Table III presents these data for the mandibular teeth. In Figs. 2 and 3, the values for the mean length ± 2 S.D. from Table II and Table III are represented schematically.

In Fig. 4, graphs are given of the values of the mean length as mentioned in Table I, compared with the values of this study.

A comparison was made between the averages calculated for the series of mean length values of the 1, 2, 3, 4, 5, 6, and 7 together for the maxilla and for the mandible as given by the different authors (Table I) and as found in this investigation (Table IV). In this

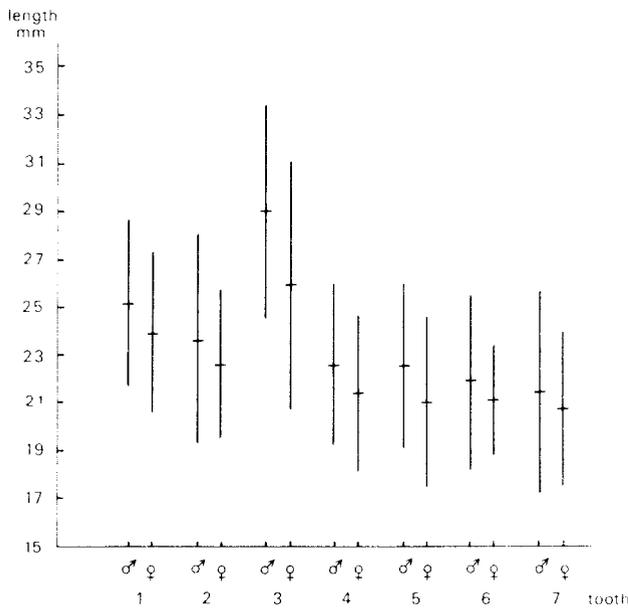


Fig. 2. Mean length ( $\bar{x}$ )  $\pm$  2 S.D. of the maxillary teeth for men ( $\sigma$ ) and women ( $\varphi$ ).

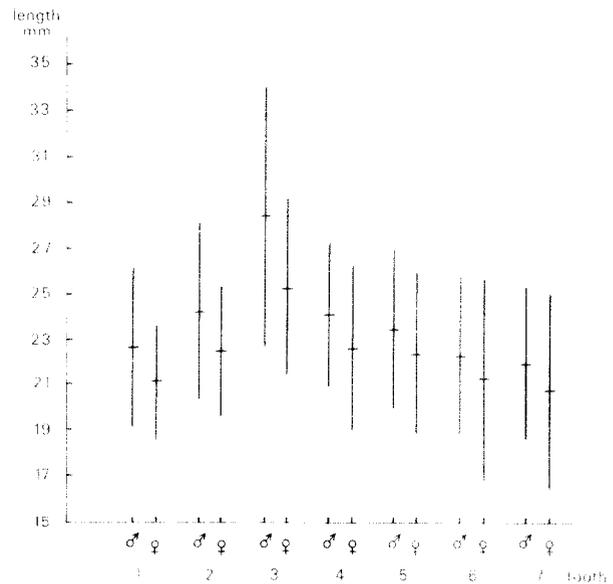


Fig. 3. Mean length ( $\bar{x}$ )  $\pm$  2 S.D. of the mandibular teeth for men ( $\sigma$ ) and women ( $\varphi$ ).

Table III. Length of mandibular teeth

Tooth (n = 50)	Men					Women				
	Mean length	S.D.	Minimum length	Maximum length	Range	Mean length	S.D.	Minimum length	Maximum length	Range
1	22.6	1.74	18.5	25.5	7.0	21.0	1.31	18.5	25.0	6.5
2	24.1	1.94	19.5	27.5	8.0	22.4	1.43	19.5	25.0	5.5
3	28.4	2.87	21.0	33.5	12.5	25.3	1.94	20.5	29.5	9.0
4	24.0	1.61	21.0	27.5	6.5	22.5	1.81	17.5	25.0	7.5
5	23.4	1.74	20.5	28.0	7.5	22.3	1.79	16.5	25.5	9.0
6	22.1	1.74	18.5	26.5	8.0	21.1	2.22	17.0	27.0	10.0
7	21.8	1.69	18.0	25.5	7.5	20.6	2.12	15.5	26.5	11.0

Lengths given in mm.

table the lowest averages appear in Drennan's<sup>9</sup> results from measurements of the teeth of Bushmen.

The relative high values found in this study may be the result of the correction for abrasion, which was not carried out in the other investigations.

In order to determine whether certain statistical methods for the comparison of two groups of observations (Student's t test) were allowed, it was investigated whether the distribution of the different groups of tooth types was normal. For this purpose, the values of the length measurements were plotted on normal probability paper. The distributions of all groups of tooth types were found to be such that the application of Student's t test was allowed.

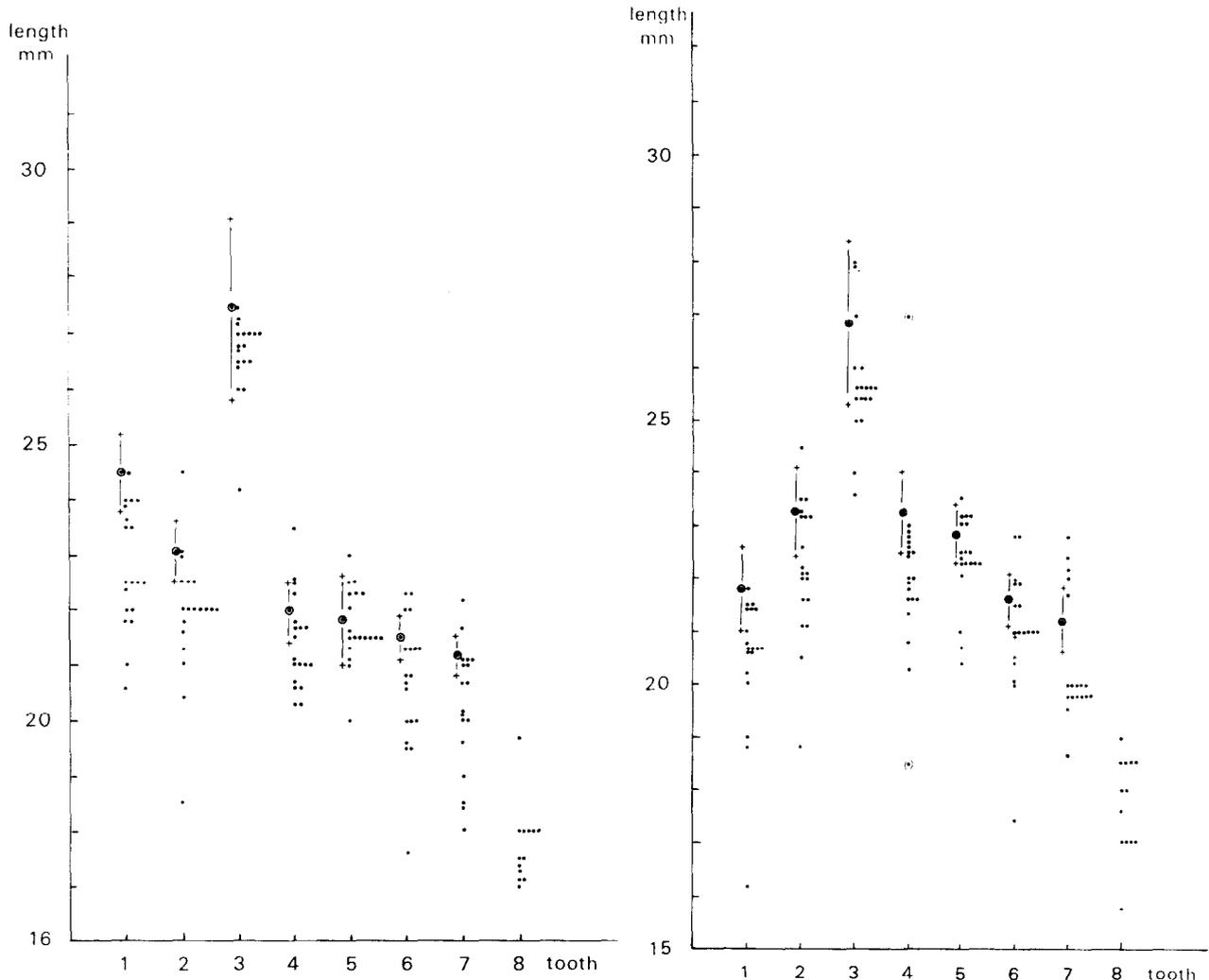
2. Table V presents the results of Student's t test used to determine whether the mean length of each tooth type was different between sexes. All differences but one were found to be statistically significant

( $t > 1.99$ ;  $\alpha = 0.05$ ), which permits the conclusion that the mean length of each tooth type was greater for men than for women.

For the design of the aiming devices, it is of more importance to know for each region to be radiographed, instead of for each tooth type, whether the tooth length is different between sexes. For this purpose, the longest tooth of each pair was selected. Table VI presents for each region the mean and S.D. of the length of the teeth obtained by selecting the longest one of each pair. A comparison was made for each region between men and women using these longest teeth.

It could be shown, in a way as described before, that the distributions of the longest teeth also permit the use of Student's t test. Table VII presents the results of these comparisons. Differences in length are significant, with  $t > 1.99$  ( $\alpha = 0.05$ ).

For all groups, the difference by sex turned out to be



**Fig. 4.** *Left*, Mean length of maxillary teeth. · = Mean length values from literature. + = Mean length values from this study for the teeth of men and women separately. ● = Idcm, for the teeth of men and women together. *Right*, Mean length of mandibular teeth.

statistically significant (men's length greater than women's). It can be concluded that for each region, the mean length of the longest tooth of the pairs is also greater for men than for women.

3. A comparison was made between the length of the first and the second incisors, the first and the second premolars, and the first and the second molars, in the maxilla and in the mandible, in men and in women, utilizing the collected teeth in pairs, each pair from one individual. The differences in length do not allow conclusions other than what is already generally known, namely, that in both men and women, the maxillary first incisor is longer than the second incisor and the mandibular second incisor is longer than the first incisor.

4. As shown in Table VIII, a positive correlation exists between the length of the pairs in all groups mentioned in No. 3. For all groups of pairs, this posi-

tive correlation is significant ( $r > 0.235$ ;  $\alpha = 0.05$ ), which means that when, for instance, the upper central incisor of a person exceeds the length of the same tooth of another person, in general the same will hold true for the upper lateral incisor.

5. Table IX presents the values found for the radiographic relevant length (r.r.l.) in the different regions of the mouth. A description of the practical use of these values for the design of the aiming devices will be given in another report.

#### SUMMARY

Length measurements were made on all types of teeth, except the third molars, extracted from male and female patients in the central part of The Netherlands. With the exception of the cuspids, all teeth were collected in pairs, which means that only the 1 and 2, the 4

**Table IV.** Averages of the series of mean length values of teeth 1, 2, 3, 4, 5, 6, and 7 together for the maxilla and the mandible as given by the different authors

Authors	Average tooth length (mm.)	
	Maxilla	Mandible
Aprile and Figun	22.36	22.09
Bjorndal and associates	23.31	22.86
Black	21.99	21.73
Broomell and Fischelis	21.84	21.62
Bouland and Lebourg	22.29	21.86
Campbell	22.93	23.24
Dewey	21.99	21.73
Dieulafé and Herpin	21.86	21.14
Drennan	20.66	20.00
Kraus and associates	22.29	22.50
Marseillier	22.29	22.24
Mörike and associates	22.73	22.23
Mühlreiter	22.73	22.97
Pucci and Reig	21.83	22.41
Sauvez and associates	21.96	21.90
Shaw	22.46	22.19
Sicher and Tandler	22.73	23.08
Wheeler	22.29	22.64
Verhoeven and associates (men)	23.77	23.77
Verhoeven and associates (women)	22.34	22.17
Verhoeven and associates (men + women)	23.06	22.97

**Table V.** Length differences between the teeth of men and women

Tooth	Difference between men and women (n = 50)	t Value (Difference is significant if t > 1.99) ( $\alpha = 0.05$ ; df = 98)
<b>Maxilla</b>		
1	Men > Women	4.11
2	Men > Women	2.97
3	Men > Women	6.93†
4	Men > Women	3.19
*	Men > Women	2.24
5	Men > Women	4.35
*	Men > Women	3.47
6	Men > Women	2.43
*	Men > Women	2.74
7	Men > Women	1.72
*	Men > Women	2.90
<b>Mandible</b>		
1	Men > Women	5.21
2	Men > Women	5.10
3	Men > Women	6.17†
4	Men > Women	4.29
5	Men > Women	3.15
6	Men > Women	2.71
7	Men > Women	3.13

\*Distance from top of buccal cusps to apex of (palatal) root measured diagonally.

**Table VI.** Length of the teeth of men and women (longest tooth of each pair) in the different regions of the mouth (n = 50)

Region	Men		Women	
	Mean length (mm.)	S.D.	Mean length (mm.)	S.D.
<b>Maxilla</b>				
Incisors	25.29	1.77	23.81	1.65
Cuspid	29.13	2.24	25.76	2.61
Premolars	23.03	1.66	21.72	1.71
*	23.14	1.75	22.13	1.75
Molars	22.42	1.82	21.51	1.21
*	24.18	1.73	22.97	1.39
<b>Mandible</b>				
Incisors	24.11	1.95	22.42	1.37
Cuspid	28.36	2.87	25.34	1.94
Premolars	24.19	1.59	23.07	1.58
Molars	22.46	1.69	21.31	2.18

\*Distance from top of buccal cusps to apex of (palatal) root measured diagonally.

**Table VII.** Comparison of the length of the teeth of men and women (longest tooth of each pair) in the different regions of the mouth (n = 50)

Region	Difference between men and women	t Value (significant for t > 1.99) ( $\alpha = 0.05$ ; df = 98)
<b>Maxilla</b>		
Incisors	Men > Women	4.33
Cuspid	Men > Women	6.93†
Premolars	Men > Women	3.88
*	Men > Women	2.89
Molars	Men > Women	2.95
*	Men > Women	3.85
<b>Mandible</b>		
Incisors	Men > Women	5.02
Cuspid	Men > Women	6.17†
Premolars	Men > Women	3.53
Molars	Men > Women	2.95

\*Distance from top of buccal cusps to apex of (palatal) root measured diagonally.

†From Table V.

and 5, or the 6 and 7 extracted from one quadrant and from one patient were used.

The measurements were made to collect data for the design of aiming devices for intraoral radiography. For this purpose, the following information was collected:

1. The mean, standard deviation, minimum, maximum, range, and distribution of the length of all different groups of tooth types (Tables II and III; Figs. 2 and 3). A comparison was made with the values found in the literature (Tables I and IV; Fig. 4).

**Table VIII.** Correlation coefficient for the length of the mentioned pairs of teeth

Teeth	Correlation coefficient (r) (Significant for $r > 0.235$ ) ( $\alpha = 0.05$ )	
	Men	Women
Maxilla		
1-2	+0.76	+0.79
4-5	+0.69	+0.66
6-7	+0.55	+0.60
Mandible		
1-2	+0.90	+0.69
4-5	+0.72	+0.59
6-7	+0.71	+0.84

2. A comparison between the length of the teeth of men and women (Tables V to VII).

3. A comparison between the length of the first and the second incisors, respectively the first and the second premolars, respectively the first and the second molars, which were collected in pairs, each pair from one person.

4. The correlation between the length of the pairs mentioned in No. 3 (Table VIII).

5. The length of the teeth for the different regions of the mouth suitable for the design of the aiming devices (Table IX).

We wish to thank all those who contributed to the collection of the teeth used for this study. For the advice given for the statistical analysis of the results of the measurements, we wish to thank the members of the staff of the Mathematical Institute of the University of Utrecht.

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**Table IX.** The radiographic relevant length (r.r.l.) of the teeth in the different regions of the mouth

Region	r.r.l. (mm)	
	Men	Women
Maxilla		
Incisors	28.5	26.3
Cuspid	32.8	30.8
Premolars*	26.8	24.8
Molars*	27.0	25.5
Mandible		
Incisors	27.0	24.8
Cuspid	32.8	28.8
Premolars	26.8	25.0
Molars	26.0	25.8

\*Results based on the values found for the distance from the top of the buccal cusps to the apex of the (palatal) root, measured diagonally.

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