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ORIGINAL ARTICLE

Crown heights in the permanent teeth of 47,XYY males

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ABSTRACT

Objective: The results in human sex chromosome aneuploidies had shown that the extra Y chromosome increases permanent and deciduous tooth crown sizes in the mesiodistal and labiolingual directions. The hypothesis of the study was that the additional Y chromosome increases the permanent tooth crown growth in a vertical dimension. We also aimed to observe possible sex difference in the permanent tooth crown height.

Material and methods: Data on 15 47,XYY males or males with an extra Y chromosome, nine male relatives (five brothers and four fathers) and 45 male and 48 female population controls had been gathered previously for Professor Lassi Alvesalo's KVANTTI Research Project. The measurements from panoramic radiographs were performed of all the applicable teeth, except the third molars on both sides of the jaws with a sliding digital calliper.

Results: All the mean tooth crown heights in the 47,XYY males were larger than in the male population controls and the differences were statistically significant in six teeth in the maxilla and 10 teeth in the mandible. Apart from few teeth, the crown heights in the 47,XYY males were larger than in their male relatives, but the difference between these groups was significant only in one tooth. The differences between sexes were statistically significant in eight teeth in the maxilla.

Conclusions: Based on previous investigations and this work, it is evident that the impact of the extra Y chromosome during tooth crown development is holistic, increasing permanent tooth sizes in three dimensions in a balanced manner.

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Introduction

The total incidence of sex chromosome abnormalities, including data from induced abortions after prenatal examinations, has been reported to be 2.34 per 1000 newborn children, or 1 out of every 426 [1]. The incidence of an XYY syndrome in that material (including the karyotypes 47,XYY and 46,XY/47,XYY) was found to be 1 per 851 live-born boys and that of karyotype 47,XYY to be 1 per 1000. The 47,XYY phenotype commonly includes tall stature, macrocephaly (33% of the 47,XYYmales), hypotonia (or decreased muscular tone) (63%), clinodactyly (52%) and hypertelorism (59%) [2]. These researchers also reported testicular enlargement for age (50%), mild resting and/or intention tremors (43%), flat feet (52%) and an increased incidence of asthma and autistic spectrum disorder (ASD) as compared with general population rates. Testosterone, luteinizing hormone and follicle-stimulating hormone levels were usually in the normal range. Birth weight and length were in the normal range in 47,XYY males, but excess growth was found to start at an approximate age of six years and the heights of adults were found to exceed the midparental target height [2]. The mean height of adult 47,XYY males was 188.9 cm, which was 12.4 cm greater than in the male population controls and 11.5 cm greater than in their male relatives [3]. The same researchers also noted that the body proportions of these patients were similar to those of the normal males. This finding suggests that the increase in growth in these patients may be mediated by direct action of the Y chromosome on the cells. The craniofacial dimensions of 47,XYY males were larger than those of normal males or females, without having any substantial effects on dimensional ratios or plane angles [4]. Dental problems were reported in 22% of XYY males including prognathic jaw with underbite (mandibular overjet) and macrodontia [2]. A total of 47,XYY males and their male relatives tended to have mesial molar occlusion, mandibular overjet and incisal open bite more often than did the population control males [5]. These aneuploidies had also an increase in palatal growth transversely and anteroposteriorly and in mandible arch length anteroposteriorly, but not so much in palatal height or mandibular width [6]. These findings in 47,XYY men are in accordance with the earlier observations that the palate becomes shallower with the addition of a sex chromosome. It is also apparent that the influence of X and Y chromosomes differs, at least regarding the magnitude of metric changes [6].

Human dental development begins with the formation of the deciduous teeth at about four weeks in utero, and all the tooth crowns apart from those of the third permanent molars reach their final size and shape between the ages of 2

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months and 8 years. Measurements of enamel and dentin thickness on radiographs of maxillary permanent incisors, canines and molars in normal females (46,XX) or males (46,XY) and individuals with sex chromosome abnormalities, such as 45,X, 45,X/46,XX (female with one X and one normal XX cell lines) and 47,XXX females, 47,XYY and 47,XXY males and 46,XY females (females with the complete form of testicular feminizing syndrome, who are insensitive to androgens), have demonstrated that the Y chromosome promotes the growth of both enamel and dentin, whereas the effect of the X chromosome on tooth crown growth seems to be restricted to enamel formation [7–13]. The enamel thickness of the teeth in 46,XY females was about equal to that in normal females or males, while the thickness of the dentin of the incisors and canines was clearly greater than that found in normal females, but about the same as in control males [7]. Increased tooth crown sizes in the mesiodistal and labiolingual directions have been observed in both the permanent and deciduous dentitions of 47,XYY males [8,14–16] and also increased permanent tooth root lengths [17], and these have been attributed to the extra Y chromosome.

The crown morphology is altered in 47,XYY males, in that the degree of shovelling of the maxillary permanent lateral incisors is greater with the palatal fossa is deeper than in their male and female first degree relatives [18]. Sex chromosomes have an effect mainly on the cusp basal area rather than cusp height, the basal area being smallest in 45,X females, those with the sharpest cusps, and becoming larger in normal women and men, and even larger in 47,XYY males, who have the bluntest cusp form [19]. It became clear that the sex chromosomes have a definite effect on cusp shape and size in all three dimensions but may not influence the developing cusps and teeth equally. It is also apparent that the influence of X and Y chromosomes differs, at least regarding the magnitude of metric changes [10,19,20].

Molecular studies have shown that the gene loci for human amelogenin, which is the main protein component of the organic matrix in enamel, are on both the X and Y chromosomes [21]. The amino acid sequences of these X and Y amelogenin genes seem to differ to some extent, however, and the transcriptional products of the X and Y chromosomes are both quantitatively and qualitatively different.

The aim of the present research was to determine whether the effect of an extra Y chromosome on permanent tooth crown growth increases crown size in a vertical dimension. We also aimed to specify the sex difference in the permanent tooth crown height.

Material and methods

The influence of sex chromosome genes on human tooth crown size was suggested as a result of a previous correlative family study (siblings and cousins) on the population of the island of Hailuoto in Finland in 1966–1968 [22]. These results then gave an impetus to Professor Lassi Alvesalo's KVANTTI (an acronym from the finnish words Kromosomaalisen VAikutukseN Tutkimus-projekTI) research project. The data for KVANTTI project was compiled mainly in 1974–1987, focusing on participants with sex chromosome aneuploidy and their first-degree relatives. All the present groups of subjects were derived from the KVANTTI material, the 15 47,XYY males or males with an extra Y chromosome (Figure 1) and nine male relative controls (five brothers and four fathers) being the same as in the earlier study by Lähdesmäki and Alvesalo in 2004 [17] (Table 1). The population controls were 45 males and 48 females who were first-degree relatives of aneuploidies other than 47,XYY males. The subjects concerned were of Finnish origin living in various parts of Finland and all the aneuploidies had a cytogenetic diagnosis performed primarily on medical grounds. The protocol for the research had been accepted by the Ethical Committee of the Faculty of Medicine at the University of Turku, Finland, in 1987. This study subjects were not at risk in any way.

Measurements

The determinations of tooth crown heights in all the study groups were performed on ortopantomograms (OPTGs) by Raija Lähdesmäki. The measurement procedures were as detailed in the previous studies by Raija Lähdesmäki [23],

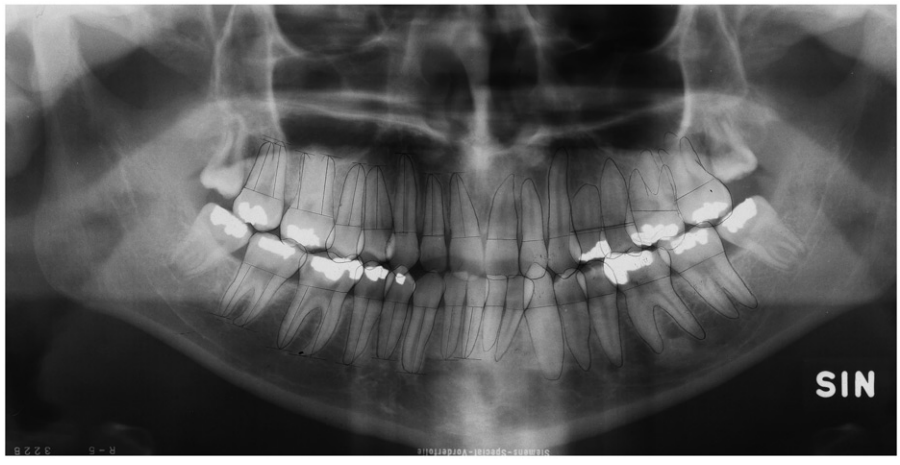

Figure 1. The dentition of a 47,XYY male at the age of 16 years.

and by Pentinpuro and co-workers [24]. The crown height was the perpendicular distance between two parallel lines, one tangential to the outer edge of the cusp or incisor edge and the other running between the mesial and distal cemento-enamel junctions. The measurements were performed of all the applicable permanent teeth, except the third molars, on the both sides of the jaws with a sliding digital calliper (Mitutoyo, digimatic 500–123U, CD-15B, Andover, England) to an accuracy of 0.01 mm. We examined the reliability of the measurements by performing double determinations on a total of 45 dental radiographs from the KVANTTI research material, representing adult 45,X females and their female and male relatives, with 15 persons in each group [17]. When double determinations of tooth crown heights of these dental radiograms were performed, the ICC ranged from 0.657 to 0.899 (Mean 0.809, SD 0.074) (see Appendix, Table AI) and the average of the differences in tooth crown heights between these determinations ranged from −0.03 mm for the right canine to −0.27 mm for the left lateral incisor in the upper jaw and from −0.20 mm for the lateral incisor on the right and the first molar on the left to −0.52 mm for the lateral incisor on the left side of the lower jaw. There was no evidence of extensive tooth wear on the dental casts or OPTGs used here, although it was possible to discern smaller amounts of wear on these records.

Statistical methods

The statistical analyses were executed with SPSS program version 20.0 (SPSS, Inc., Chicago, IL). The statistical significance of the results was determined at a level of $p < .05$. To verify the

Table 1. Age distributions in the 47,XYY males and control groups.

Study group	Mean age (years)	SD	Age range (years)	Median	*n*
47,XYY males	18.6	7.4	10.0–36.7	16.2	15
Male population controls	32.4	16.2	11.6–67.5	34.3	45
Female population controls	30.0	12.0	9.7–59.1	29.6	48
47,XYY males with a male relative	17.9	7.5	10.0–36.7	16.2	9
Male relatives of the 47,XYY males	27.6	13.0	11.9–42.7	31.9	9

Table 2. Mean tooth crown heights (Mean) (mm) and relative differences (RD%).

	47,XYY males		Population control males				Population control females			
Tooth	Mean (SD)	*n*	Mean (SD)	*n*	p^a	RD%[c]	Mean (SD)	*n*	p^b	RD%[d]
Maxilla										
Right second molar	11.3 (0.8)	9	10.2 (0.8)	31	.001***	9.8	9.9 (0.8)	38	.446	2.3
First molar	11.7 (0.9)	11	10.5 (0.8)	30	.000***	10.4	10.1 (0.9)	32	.249	3.4
Second premolar	11.1 (1.0)	11	10.3 (0.7)	30	.038*	7.3	10.0 (1.0)	35	.354	3.1
First premolar	11.6 (1.0)	12	11.2 (0.7)	26	.497	2.9	10.2 (0.9)	32	.000***	8.9
Canine	12.3 (0.9)	15	11.9 (1.2)	36	.383	3.3	11.1 (0.8)	40	.003**	6.5
Lateral incisor	10.6 (1.1)	12	10.3 (0.9)	32	.580	2.8	9.7 (0.8)	40	.007**	6.3
Central incisor	12.0 (1.3)	15	11.3 (0.9)	38	.167	5.9	10.6 (0.8)	40	.002**	5.9
Left central incisor	11.8 (1.3)	15	11.1 (0.8)	36	.015*	6.5	10.6 (0.8)	40	.047*	4.4
Lateral incisor	10.7 (1.1)	14	10.0 (0.9)	36	.055	6.0	9.6 (0.8)	39	.070	4.5
Canine	12.4 (1.3)	12	12.1 (1.2)	38	.709	2.4	11.0 (1.0)	39	.000***	9.4
First premolar	11.9 (1.0)	11	11.1 (0.9)	29	.116	6.2	10.5 (1.1)	35	.043*	5.7
Second premolar	10.9 (1.1)	13	10.6 (1.0)	29	.629	2.8	9.9 (1.0)	33	.017*	6.7
First molar	12.1 (1.0)	13	10.7 (0.8)	30	.000***	11.8	10.3 (1.1)	31	.258	3.6
Second molar	11.2 (0.8)	12	10.1 (0.8)	32	.002**	9.5	10.1 (0.9)	31	.974	0.5
Mandible										
Right second molar	11.5 (0.9)	12	10.1 (1.0)	29	.000***	12.8	10.0 (0.8)	27	.891	1.0
First molar	11.6 (0.9)	11	9.9 (0.8)	25	.000***	14.2	9.8 (0.6)	24	.669	1.8
Second premolar	11.2 (1.3)	9	9.7 (0.9)	32	.000***	13.6	9.4 (0.9)	26	.455	3.2
First premolar	11.2 (1.0)	14	9.8 (0.9)	41	.000***	12.3	9.6 (1.0)	41	.506	2.4
Canine	11.7 (1.3)	13	10.5 (1.1)	44	.003**	10.8	10.1 (1.2)	43	.135	4.6
Lateral incisor	9.8 (1.3)	13	8.8 (0.8)	44	.003**	10.5	8.5 (1.0)	46	.486	2.7
Central incisor	9.0 (1.3)	14	8.4 (0.9)	42	.074	6.9	8.0 (0.7)	46	.132	4.5
Left Central incisor	8.8 (1.2)	14	8.3 (0.8)	42	.149	5.6	7.9 (0.8)	46	.139	4.2
Lateral incisor	9.5 (1.4)	14	8.7 (0.8)	45	.146	8.5	8.4 (0.8)	47	.093	4.2
Canine	11.5 (1.5)	14	10.0 (1.1)	43	.000***	12.3	9.8 (1.1)	44	.583	2.4
First premolar	10.9 (0.9)	13	9.7 (1.0)	41	.001***	10.7	9.3 (0.9)	40	.122	4.3
Second premolar	10.4 (0.8)	8	9.4 (0.9)	31	.017*	9.2	9.0 (0.8)	28	.162	4.4
First molar	10.9 (1.6)	10	9.7 (0.7)	22	.128	10.8	9.4 (0.7)	21	.445	3.0
Second molar	11.3 (1.2)	12	10.0 (0.9)	29	.001***	11.2	9.5 (1.0)	28	.132	5.1

Results were considered statistically significant, when $p < .05$.
* $= p < .05$;
** $= p < .01$;
*** $= p \leq .001$.
Tukey's HSD test was used as a post-hoc test and if equality of variances could not be assumed Tamhane's T2 test was used (p values marked with gray color).
RD% = (CH1 − CH2)/CH1 × 100% (where RD% = relative difference (in percent) between the mean tooth crown heights in two groups, CH1 = mean of the tooth crown heights in one group and CH2 = mean of the tooth crown heights in another group).
[a]The 47,XYY males vs population control males.
[b]The population control males vs population control females.
[c]The relative differences (in percent) in the tooth grown heights between the 47,XYY males and population control males.
[d]The relative differences (in percent) in the tooth grown heights between the population control males and population control females.

reliability of the measurements, coefficients of intra-class correlation (ICC) for the double determinations on a total of 45 dental radiographs from the KVANTTI material and the average of the differences in tooth crown heights with respect to these measurements were calculated [25] (see Appendix Table AI). An additional statistical evaluation of intra-examiner precision was performed by comparing the two measurements with the paired samples t-test. Statistically significant differences between these two determinations were found only in the four incisors in the mandible.

Mean tooth crown heights of the 47,XYY males and the population control males and females were compared with ANOVA. Tukey's HSD test was used as a post-hoc test and if equality of variances could not be assumed Tamhane's T2 test was used. Mean tooth crown heights were compared between the 47,XYY males and their male relatives with the paired samples t-test, and if the differences between the two groups were not normally distributed Wilcoxon's signed ranks test was used. The relative difference in mean tooth crown heights between two groups was determined for each tooth using the formula: RD% = (CH1− CH2)/CH1 × 100% (where RD% = relative difference (in percent) between the mean tooth crown heights in two groups, CH1 = mean of the tooth crown heights in one group and CH2 = mean of the tooth crown heights in another group). The mean relative difference (MRD%) was calculated from the RD% values of the teeth in the tooth group.

Means of the differences in tooth crown heights between the right and left sides of the jaws in the 47,XYY males, their male relatives, the population control males and population control females were also compared using the paired samples t-test and Wilcoxon's signed ranks test in order to look for directional asymmetry [24]. A value for the fluctuating asymmetry (FA) was obtained by dividing the absolute difference between the sides by the absolute mean sizes of the left and right teeth [25], FA = abs (R − L)/((R + L)/2). In this work, FA values were calculated for every subject by dividing the absolute tooth crown height difference by the absolute mean crown height on the left and right sides separately. The mean FA was then calculated from the FA values for each tooth and the independent samples t-test have used to compare the FA values between the two groups. If the FA values were not normally distributed (as when comparing the 47,XYY males with their male relatives), the Mann–Whitney test was used.

Results

The mean permanent tooth crown heights in the 47,XYY males were larger than those in the male population controls in the all the teeth and the differences between these groups were statistically significant in six teeth in the maxilla and 10 teeth in the mandible (Table 2). The mean RD% was 6.3% in the maxilla, 10.7% in the mandible and 8.5% in the whole dentition and the average MRD% values were 5.9, 10.8, 8.3%, respectively. The MRD% values for the tooth groups were 10.4% in molars, 4.8% in premolars, 4.8% in canines and 5.3% in incisors in the maxilla, while these values were 12.3, 11.5, 11.6, 7.9% in mandible. Apart from few teeth the 47,XYY males had larger mean tooth crown heights than their male relatives (Table 3). The male population controls had larger crowns than the female controls and the differences between these two groups were statistically significant in eight teeth in the maxilla. When comparing these two population control groups the average RD% was 5.1% in the maxilla, 3.4% in the mandible and 4.3% in the whole dentition. The average MRD% values were 5.5, 3.4, 4.5%, respectively. The MRD% values were 2.5% in molars; 6.1 in premolars; 8.0% in canines; 5.3 in incisors in the maxilla, while these values were 2.7%; 3.6%; 3.5%; 3.9% in the mandible.

Table 3. Mean tooth crown heights (mm) in the 47,XYY males and their male relatives.

	47,XYY males		Male relatives		
Tooth	Mean (SD)	*n*	Mean (SD)	*n*	*p*
Maxilla					
Right second molar	11.2 (0.6)	4	10.5 (0.7)	4	.119
First molar	12.3 (0.7)	4	11.3 (0.3)	4	.144
Second premolar	11.2 (1.4)	4	10.7 (0.3)	4	.465
First premolar	11.4 (1.5)	5	11.2 (1.1)	5	.686
Canine	12.6 (0.8)	6	11.9 (1.4)	6	.249
Lateral incisor	11.1 (1.1)	4	10.7 (1.4)	4	.703
Central incisor	11.8 (0.9)	7	11.3 (1.6)	7	.222
Left central incisor	11.6 (0.9)	7	11.1 (1.2)	7	.070
Lateral incisor	11.0 (0.9)	7	10.5 (1.3)	7	.499
Canine	12.6 (0.9)	4	12.5 (1.0)	4	.810
First premolar	12.2 (1.2)	4	11.6 (1.2)	4	.093
Second premolar	11.0 (1.5)	6	10.8 (0.7)	6	.463
First molar	12.2 (1.2)	6	11.3 (0.9)	6	.249
Second molar	11.0 (0.6)	6	11.1 (0.7)	6	.753
Mandible					
Right second molar	11.8 (1.1)	5	10.6 (0.4)	5	.080
First molar	12.3 (0.9)	2	11.0 (0.1)	2	.180
Second premolar	11.2 (1.6)	6	10.4 (0.4)	6	.336
First premolar	11.5 (0.9)	8	10.9 (0.8)	8	.093
Canine	12.3 (0.9)	7	11.4 (0.8)	7	.017*
Lateral incisor	10.2 (0.9)	9	9.7 (0.9)	9	.184
Central incisor	9.4 (1.1)	9	9.0 (1.2)	9	.441
Left central incisor	9.0 (1.1)	9	9.2 (1.1)	9	.594
Lateral incisor	9.9 (1.1)	9	9.5 (1.1)	9	.314
Canine	11.7 (1.1)	8	10.9 (0.6)	8	.058
First premolar	10.9 (0.8)	8	10.1 (0.9)	8	.123
Second premolar	9.7 (0.7)	3	10.0 (0.6)	3	.109
First molar	10.0 (1.3)	4	10.9 (0.9)	4	.273
Second molar	11.0 (1.6)	5	10.9 (0.5)	5	.686

Results were considered statistically significant, when $p < .05$.
*= $p < .05$;
**= $p < .01$;
***= $p \leq .001$.
Mean tooth crown heights between the 47,XYY males and their male relatives were compared with paired samples t-test and if the difference of the two groups were not normal distributed Wilcoxon's signed ranks test (marked with gray colour) was used.

The tooth crown heights were greater on the right side than on the left in three or four teeth in the upper jaws and in all the teeth in the lower jaws of the 47,XYY males and of male and female population controls. The differences in tooth crown heights between the two sides of the jaw were statistically significant only in the premolars and molars in the mandibles of the population control females (Table 4). There was only one significant difference in FA values between the 47,XYY males and their male relatives, or between the male and female population controls, while no significant difference was found in FA values between the

Table 4. Mean of differences (MD) (mm) in tooth crown heights between the right and left sides of the jaws in the 47,XYY males and population controls.

	47,XYY males			Population control males			Population control females		
Differences	MD (SD)	*n*	*p*[a]	MD (SD)	*n*	*p*[b]	MD (SD)	*n*	*p*[c]
Maxilla[d]									
Diff 17–27	−0.208 (1.13)	9	.597	0.060 (0.83)	27	.707	−0.112 (0.86)	29	.489
Diff 16–26	−0.414 (1.12)	10	.271	−0.196 (0.99)	27	.316	−0.142 (0.82)	29	.359
Diff 15–25	0.326 (1.46)	10	.499	−0.103 (0.87)	25	.561	0.049 (0.83)	30	.748
Diff 14–24	−0.276 (1.07)	11	.412	−0.056 (0.91)	23	.773	−0.187 (0.95)	29	.299
Diff 13–23	−0.093 (0.79)	12	.694	−0.218 (0.89)	36	.151	0.112 (0.67)	38	.310
Diff 12–22	0.104 (0.65)	11	.606	0.321 (0.91)	31	.058	0.027 (0.63)	38	.797
Diff 11–21	0.155 (0.56)	15	.297	0.180 (0.59)	36	.074	0.034 (0.36)	40	.550
Mandible[e]									
Diff 41–31	0.208 (0.51)	14	.152	0.054 (0.51)	41	.501	0.044 (0.35)	45	.410
Diff 42–32	0.331 (0.57)	13	.057	0.023 (0.72)	44	.832	0.143 (0.60)	46	.111
Diff 43–33	0.258 (1.18)	13	.447	0.294 (0.96)	42	.054	0.216 (0.98)	42	.160
Diff 44–34	0.693 (1.14)	12	.059	0.154 (0.84)	39	.256	0.327 (0.80)	38	.016*
Diff 45–35	0.587 (0.90)	7	.136	0.319 (0.94)	26	.095	0.491 (0.48)	21	.000***
Diff 46–36	0.517 (1.01)	9	.164	0.324 (0.78)	20	.080	0.380 (0.41)	21	.000***
Diff 47–37	0.517 (1.01)	11	.245	0.168 (0.89)	26	.345	0.370 (0.66)	26	.008**

Statistical evaluation performed using the paired samples t-test. *p* Values are considered statistically significant, when $p < .05$.
*$= p < .05$;
**$= p < .01$;
***$= p \leq .001$.
Statistical significance of the mean of the differences in tooth crown heights between the right and left sides of the jaws in.
[a]the 47,XYY males,.
[b]the population control males and.
[c]the population control females.
[d]Mean of the differences in tooth crown heights between the second molars (Diff 17–27) … and central incisors (Diff 11–21) on the right and left sides of the maxilla.
[e]Mean of the differences in tooth crown heights between the central incisors (Diff 41–31) … and second molars (Diff 47–37) on the right and left sides of the mandible.

47,XYY males and male population controls (see Appendix, Table AII).

Discussion and conclusion

The present results showed that the excess growth of the permanent tooth crowns of the 47,XYY males in a vertical direction as compared with the population control males or females was parallel with previous measurements of the mesiodistal and labiolingual dimensions of deciduous and permanent tooth crowns obtained from dental casts [7,14–16,26] and of the mesiodistal dimension of permanent tooth crowns as obtained from radiographs [7,27]. Almost all the mean tooth crown heights in the male relatives of the present aneuploidies were between the values for the 47,XYY males and for the male population controls, as was also the case with tooth root lengths [17]. Alvesalo and co-workers observed [14,22] that all the mean permanent tooth sizes were larger in the mesiodistal direction in the males than in the females and that this was also the case in the labiolingual direction. In order to compare the mean permanent tooth crown sizes in the three dimensions, we calculated the RD% values between the males and females in the previous study performed by Alvesalo et al. in 1975 [7,14]. The average RD% between sexes was 3.4% in the maxilla and 3.2% in the mandible in the mesiodistal direction, and 3.2 and 2.2%, respectively, in the labiolingual direction. The mean difference of all the root lengths between the males and females was found to be 4%, and between 47,XYY males and normal males 9% [17]. We observed that the differences in tooth crown heights between male and female population control groups in this work (average RD% 5.1% in the maxilla, 3.4% in the mandible and 4.3% in the all crowns) were of the same magnitude as the values recorded earlier in the mesiodistal and labiolingual directions of tooth crowns and in the lengths of permanent tooth roots.

The mean reduction in tooth crown heights in the tooth groups in the 45,X females compared to the female population controls was largest in the molars (13.7%) and premolars (17.4%) and smallest in the canines (4.5%) and incisors (0.4%) of the maxilla in the previous work by Pentinpuro and research group [24]. The average reduction values in the mandible were large (10.8–10.2%) in all tooth groups except for the incisors (8.7%). The present results showed that, excluding the premolar area in the maxilla, MRD% values in the 47,XYY males and the mean relative reduction values in the 45,X females were of the same magnitude.

In conclusion, based on previous investigations and the present findings it would appear that the impact of the extra Y chromosome during tooth crown development is holistic, increasing the permanent tooth size in the three dimensions in a balanced manner.

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Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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Appendix

Table AI. Coefficients of intra-class correlation (ICC) values and the mean of the differences (Diff (mm)) in tooth crown height between the double determinations performed by Raija Lähdesmäki.

Tooth	*n*	ICC	Diff (SD)
Maxilla			
Right second molar	43	0.889	−0.14 (0.5)
First molar	39	0.821	0.25 (0.7)
Second premolar	43	0.882	−0.04 (0.7)
First premolar	38	0.787	−0.09 (0.8)
Canine	44	0.833	−0.03 (0.6)
Lateral incisor	44	0.773	0.16 (0.6)
Central incisor	45	0.880	0.07 (0.5)
Left central incisor	45	0.894	−0.11 (0.5)
Lateral incisor	44	0.663	−0.27 (0.9)
Canine	45	0.840	−0.09 (0.7)
First premolar	40	0.861	−0.16 (0.6)
Second premolar	42	0.762	−0.10 (0.8)
First molar	39	0.818	0.13 (0.5)
Second molar	42	0.894	0.05 (0.5)
Mandible			
Right second molar	41	0.803	−0.36 (0.6)
First molar	37	0.899	−0.44 (0.6)
Second premolar	40	0.776	−0.46 (0.6)
First premolar	44	0.797	−0.26 (0.4)
Canine	45	0.785	−0.23 (0.5)
Lateral incisor	44	0.657	−0.20 (0.4)
Central incisor	43	0.692	−0.27 (0.6)
Left central incisor	45	0.660	−0.36 (0.5)
Lateral incisor	45	0.740	−0.52 (0.7)
Canine	44	0.828	−0.46 (0.7)
First premolar	43	0.895	−0.44 (0.6)
Second premolar	38	0.805	−0.31 (0.6)
First molar	37	0.883	−0.20 (0.4)
Second molar	41	0.842	−0.28 (0.6)

Table AII. Mean fluctuating asymmetry (FA) in tooth crown heights between the right and left sides of the jaws in the 47,XYY males and population control males.

	47,XYY males		Population control males		
Teeth	FA (SD)	*n*	FA (SD)	*n*	*p*
Maxilla					
FA 17–27	0.078 (0.06)	9	0.061 (0.05)	27	.441
FA 16–26	0.080 (0.05)	10	0.079 (0.05)	27	.979
FA 15–25	0.104 (0.08)	10	0.065 (0.05)	25	.088
FA 14–24	0.079 (0.06)	11	0.070 (0.04)	23	.580
FA 13–23	0.052 (0.04)	12	0.060 (0.05)	36	.591
FA 12–22	0.051 (0.03)	11	0.074 (0.06)	31	.247
FA 11–21	0.036 (0.03)	15	0.045 (0.03)	36	.351
Mandible					
FA 41–31	0.039 (0.04)	14	0.046 (0.04)	41	.565
FA 42–32	0.060 (0.03)	13	0.062 (0.06)	44	.867
FA 43–33	0.077 (0.06)	13	0.072 (0.06)	42	.831
FA 44–34	0.092 (0.07)	12	0.076 (0.04)	39	.316
FA 45–35	0.083 (0.06)	7	0.081 (0.07)	26	.926
FA 46–36	0.083 (0.05)	9	0.070 (0.05)	20	.512
FA 47–37	0.072 (0.05)	11	0.065 (0.06)	26	.695

Statistical evaluation performed using the independent samples t-test. Results were considered statistically significant, when $p < .05$.
*$= p < .05$;
**$= p < .01$;
***$= p \leq .001$.