Dental characteristics in Williams syndrome: a clinical and radiographic evaluation

Stefan Axelsson, Tore Bjørnland, Inger Kjær, Arvid Heiberg and Kari Storhaug

Department of Orthodontics and Department of Oral Surgery and Oral Medicine, Faculty of Dentistry, University of Oslo, Oslo, Norway; Department of Orthodontics, Faculty of Health Sciences, University of Copenhagen, Copenhagen, Denmark; Department of Medical Genetics, University Hospital (Rikshospitalet), Oslo, Norway; TAKO-Centre, Resource Centre for Oral Health in Rare Medical Conditions, Oslo, Norway

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Williams syndrome is a rare congenital syndrome with distinctive craniofacial features, cardiovascular abnormalities, and behavior characteristics including mental retardation. The dental abnormalities have received scant attention in previous literature. The aim of this study was to describe dental characteristics in individuals with Williams syndrome. In a group of 41 individuals more than 10 years of age, 40.5% had agenesis of one or more permanent teeth and 11.9% had agenesis of 6 permanent teeth or more. The mesio-distal and labio-lingual dimensions of permanent tooth crowns were measured on 31 dental study casts from individuals older than 12 years. The mesio-distal and labio-lingual dimensions were significantly smaller compared with a reference sample. An analysis of tooth morphology was performed on the same dental study casts revealing altered tooth morphology. A high proportion of maxillary and mandibular incisors was tapered or screwdriver shaped. An evaluation of taurodontism on mandibular permanent molars was performed using a metric crown-body/root ratio. However, most of the molars rated as being taurodontic had short or extremely short total tooth lengths and could thus be rated taurodontic without meeting the classical definition. The results of this study indicate that although there is variation in dental development in individuals with Williams syndrome, agenesis of permanent teeth in combination with aberrations in tooth size and morphology may affect dental esthetics and complicate orthodontic and prosthodontic treatment. □ *Hypodontia; oligodontia; tooth morphology; tooth size; Williams syndrome*

Stefan Axelsson, Department of Orthodontics, Faculty of Dentistry, University of Oslo, P.O. Box 1109, Blindern NO-0317 Oslo, Norway. Tel. +47 22 85 21 08, fax. +47 22 85 23 46, e-mail. stefan@odont.uio.no

Developmental anomalies of the dentition are frequently observed in individuals with various craniofacial syndromes. Aberrations in number, size, shape, and position of teeth may lead to disturbances in dental occlusion, oral function, orofacial esthetics, and may complicate dental treatment.

Williams syndrome (WS) is a rare congenital disorder which was first described in 1961 as an association of supravalvular aortic stenosis and mental retardation in 4 children with characteristic facies (1). Beuren et al. (2) described the syndrome independently and expanded the phenotype to include peripheral pulmonary artery stenosis and dental malformations.

The true incidence is unknown, although it is estimated to be 1 in 20,000 live births (3). The syndrome affects both sexes equally; it can occur in all ethnic groups and has been identified throughout the world.

The diagnosis is based on recognition of the characteristic pattern of dysmorphic facial features, developmental delay, short stature, connective tissue abnormalities affecting the cardiovascular organs, a unique cognitive profile, learning difficulties, and sometimes transient infantile hypercalcemia (3–5).

In 1993, a hemizygotous microdeletion of chromosome 7q11.23 encompassing the elastin gene (ELN) was discovered (6). The microdeletion is detectable by fluorescent in situ hybridization (FISH) analysis in more than 90% of individuals with the clinical phenotype of WS (7, 8).

Williams et al. (1) noted that some of the children had dental malocclusion and mandibular prognathism, but did not consider these findings part of the syndrome. The two male children in the report by Beuren et al. (9) demonstrated agenesis of deciduous and permanent teeth, abnormal bud-shaped deciduous maxillary molars, small permanent incisors, and broad maxillary and small mandibular dental arches causing bilateral posterior scissors-bite. The girls had similar but less pronounced dental malformations.

Other studies have reported increased frequency of dental abnormalities, e.g. hypodontia, microdontia, invagination of maxillary incisors, small and slender roots, pulp stones, increased space between teeth, enamel hypoplasia, high prevalence of dental caries, and malocclusion (3, 10–13). These findings were generally reported in medical reviews of limited numbers of cases with WS, and only few have included a systematic and comprehensive oral examination.

Hertzberg et al. (14) reported a comprehensive study of the oral characteristics in 45 individuals with WS aged from 13 months to 28 years, giving prevalence rates of different dental findings, e.g. tooth abnormalities, dental

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caries, and malocclusion traits. Fearne at al. (15) reported on the dental findings from clinical and radiological examination of 37 individuals with WS 2 to 24 years, e.g. caries in the deciduous dentition, hypodontia, and mineral content in deciduous incisors.

Congenital numerical variations of teeth, i.e. hypodontia and supernumerary teeth, are among the most common deviations in the permanent dentition. Both irregularities can occur as isolated traits or in association with craniofacial aberrations and syndromes (16). The coexistence of hypodontia and other developmental anomalies of the dentition, such as altered size and shape of the teeth, e.g. peg-shaped incisors, short roots, and taurodontism, indicates an increased sensitivity to developmental anomalies in affected individuals (17–20).

Reduced mesio-distal dimensions of teeth have been described in individuals with congenital agenesis of one or more permanent teeth (21–24). Few authors, however, have performed metric analyses on the labio-lingual dimensions of all permanent teeth, either on healthy individuals or on individuals with craniofacial aberrations and syndromes (24–26).

Alterations in tooth crown morphology have also been described in individuals with agenesis of permanent teeth and/or in different genetic syndromes. The altered crown morphology most often reported is conical or peg-shaped incisors (20, 27).

The overall purpose of this study was to establish the prevalence of clinical and radiographic dental abnormalities within a well-defined population of WS.

Subjects and methods

This study was performed at the Dental Faculty, University of Oslo, and at the TAKO-center, a national interdisciplinary resource center for oral health in rare medical conditions (conditions with a frequency of 1 per 10,000 inhabitants or less). Health workers from different disciplines refer patients to the center for diagnostic purposes, oral treatment planning, and treatment of complicated cases. Most of the patients in this study were recruited from the TAKO-center, but also from the members of the Norwegian Williams Syndrome Association.

The total population consisted of 59 individuals (22 M, 37 F) with a clinical and/or cytogenetic diagnosis of WS syndrome made by experienced pediatricians and geneticists. The mean age was 15.5 years (*s* 8.2) with an age range of 3.3 to 44.4 years.

The following dental anomalies in the permanent dentition were assessed clinically and studied in panoramic radiographs and/or dental study casts; dental caries, dental restorations, enamel hypomineralization or enamel defects, agenesis of teeth, supernumerary teeth, invaginations, ectopic eruption, impaction and/or retention, size and shape of tooth crowns, and taurodontism. All assessments and measurements were made by one investigator (S.A.).

Panoramic radiographs of good quality were available for 54 individuals. In order to assess agenesis of permanent teeth, only individuals older than 10 years of age were selected. The final sample for assessment of tooth agenesis therefore comprised 42 individuals (17 M, 25 F). Agenesis of permanent teeth, excluding 3rd molars, was recorded from the panoramic radiographs. A teeth were considered to be congenitally missing when no mineralization of the crown could be seen.

Dental casts from 32 individuals were available for measurements of tooth crown dimensions and assessment of tooth crown morphology on permanent teeth. One study model was excluded due to inadequate reproduction of all teeth. The final sample thus comprised 31 pairs of study models (12 M, 19 F) from individuals older than 12 years.

For assessment of taurodontism and tooth length of permanent mandibular molars, 14 panoramic radiographs were excluded; 10 individuals below 8 years of age; missing mandibular 1st and 2nd molars in 2 individuals, and poor quality of the panoramic radiographs in 2 individuals. Forty panoramic radiographs were thus assessed (17 M, 23 F).

The mesio-distal and labio-lingual dimensions of the dental crowns were measured using procedures as described by Lundström (28) and Moorrees et al. (29), respectively. The mesio-distal crown dimension of a permanent tooth crown was obtained by measuring the greatest distance between the contact points on the approximal surfaces using a caliper held parallel to both the occlusal and buccal/labial surfaces. The labio-lingual dimension was recorded as the maximal distance between the labial and palatal/lingual tooth surfaces in a plane perpendicular to that of which the mesio-distal dimension was measured. All permanent teeth that were fully erupted and had no dental restorations approximal and/or buccal/lingual were measured. The measurements were done with a digital sliding caliper with an electronic scale and digital output (Digital 6, Mauser, Isny, Germany). The caliper had sharpened beaks to facilitate approximal access and an accuracy of 0.01 mm. The measurements were collected by computer software and exported into a statistical program. The mesio-distal and labio-lingual dimensions of right and left side were obtained, but in the absence of significant differences between the sides the values were pooled in the final analysis. The mesio-distal and the labio-lingual measurements were compared with standard mesio-distal and labio-lingual dimensions reported by Townsend (25).

Assessment of tooth crown morphology on permanent teeth was performed only on teeth that were fully erupted and without dental restorations.

The permanent mandibular 1st and 2nd molars were selected for analysis of taurodontism and tooth length for several reasons. The 1st mandibular molar is considered to be one of the most stable teeth in the dentition in relation

to agenesis of teeth (19, 34). The entire outline of crowns and roots of the mandibular molars is usually clearly evident on a panoramic radiograph. Exclusion criteria for assessment of taurodontism included teeth with fused pyramidal roots, incomplete apical formation, and undetectable root furcations.

Assessment of taurodontism was based on the method described by Seow & Lai (19). The crown-body/root ratio (CB/R ratio) and the total tooth lengths were calculated to the nearest 0.1 mm. Since a ratio was calculated, the magnification factor in the vertical dimension of the panoramic radiograph had no influence.

The study protocol was reviewed and recommended by the regional committee for medical research ethics (Health Region II). Informed consent was obtained from all participants and from their parents or guardians.

Error of the method

Measurement errors of the mesio-distal and labio-lingual dimensions were analyzed by selecting 10 pairs of study models at random and performing a second measurement 2 weeks later to check intra-examiner reproducibility. Student's *t* test was used to analyze any significant differences between the 1st and 2nd measurements. A mean difference of 0.03 mm was found for the mesio-distal dimensions and 0.02 mm for the labio-lingual dimensions. The differences between the 1st and 2nd measurements were not significant.

The same 10 pairs of study models were also used to re-score the morphology of the teeth. This second session gave the teeth the same score as the first session, indicating good intra-observer replicability.

Measurement errors of the assessments of taurodontism were analyzed by selecting 10 panoramic radiographs at random and performing a 2nd measurement 2 weeks later to check intra-examiner reproducibility. Reliability of 2 repeated measurements was assessed using an intra-class correlation statistics as a geometric average. Reliability was moderate for both measures (0.63 for crown/body and 0.52 for body/root).

The average lengths of mandibular 1st and 2nd molars given by Schalk-van der Weide (24) were used as an indicator of normal mandibular tooth lengths.

Statistical analyses

Data from all measurements and assessments were transferred to a statistical program (SPSS® Base 10.0, SPSS Inc., Chicago, Il., USA). The statistical differences between the arithmetic means of all measurements in the study populations and the chosen reference groups were compared using Student's *t* test for independent data.

Results

The prevalence of agenesis of one or more permanent teeth in the present sample was 40.5% (17 out of 42 individuals). There were no indications of differences in prevalence of tooth agenesis between the sexes, between maxilla and mandible or between right and left side. The findings were compared with the results from Oslo University Craniofacial Growth Archive (30), in which agenesis of one or more teeth in the general Norwegian population was calculated to 6.5% for both sexes combined.

The missing permanent teeth in the maxilla usually included 2nd premolars, 1st premolars, and lateral incisors. In the mandible, most commonly 2nd premolars, 1st premolars, and central incisors.

Most individuals with hypodontia had agenesis of less than 4 permanent teeth (12/17), but 5 individuals had agenesis of more than 6 teeth with a maximum of 12 teeth. The frequency of agenesis of more than 6 teeth was 11.9% (5/42). There was a clear dominance of males in this subgroup (4/5), but no differences could be detected between maxilla and mandible or between right and left side. The results from the Oslo University Craniofacial Growth Archive showed that only 0.1% had agenesis of 6 teeth or more (30). Figure 1 shows an 8-year-old female participant with agenesis of maxillary lateral incisors.

The mesio-distal dimensions of maxillary and mandibular tooth crowns for males and females are given in Tables 1 and 2. Nearly all dimensions differed significantly from the reference values given by Townsend (25). The proportional differences between the study group and the reference group were greater in the males, with an overall proportional difference of 9.2%, while the females had an overall proportional difference of 8.3%.

The labio-lingual dimensions of maxillary and mandibular tooth crowns for males and females are given in Tables 3 and 4. Compared with the reference group, most labio-lingual dimensions in the study group were significantly smaller, with few exceptions. The proportional differences of the mean labio-lingual dimensions were only

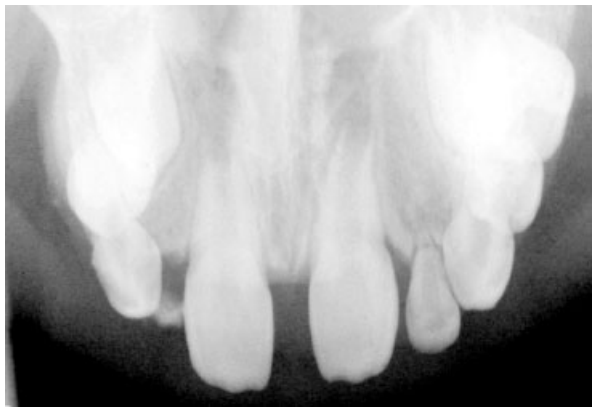

Fig. 1. Intraoral radiograph of the maxillary incisor area from an 8-year-old female showing agenesis of the maxillary lateral incisors and deviant shape of the central incisors.

Table 1. Mesio-distal dimensions in mm of maxillary and mandibular teeth in males

	Present study			Townsend, 1983			
	No. of teeth	Mean	*s*	No. of teeth	Mean	*s*	Significance
Maxilla							
Central incisor	20	8.36	0.77	87	8.71	0.52	*
Lateral incisor	17	6.00	0.47	78	6.77	0.53	***
Cuspid	17	7.30	0.35	65	7.98	0.40	***
1st premolar	12	6.46	0.43	61	7.02	0.40	***
2nd premolar	8	6.31	0.22	66	6.74	0.44	***
1st molar	15	9.63	0.42	75	10.65	0.51	***
2nd molar	10	9.06	0.47	59	10.33	0.57	***
Mandible							
Central incisor	19	4.84	0.54	85	5.43	0.30	***
Lateral incisor	19	5.36	0.46	82	6.00	0.33	***
Cuspid	19	6.31	0.42	65	6.91	0.34	***
1st premolar	17	6.28	0.47	57	7.14	0.47	***
2nd premolar	11	6.92	0.51	62	7.24	0.45	*
1st molar	17	10.28	0.63	65	11.42	0.61	***
2nd molar	13	9.73	0.31	49	10.95	0.65	***

s = standard deviation.
* Significant at $P < 0.05$; *** significant at $P < 0.001$.

slightly greater in the males, with an overall proportional difference of 7.8%, while the females had an overall proportional difference of 7.3%.

The study sample was subdivided into 2 groups, a 'non-agenesis group' and an 'agenesis-group', in order to detect any differences between the groups in mesio-distal and labio-lingual dimensions. The subgroups thereby became very small and statistics had to be used with caution. No detectable differences between the groups were found, indicating that individuals with WS may have small teeth regardless of tooth agenesis.

The morphological deviations of maxillary and mandibular incisors are presented in Table 5. A large proportion of maxillary and mandibular incisors in both groups was rated as tapered, with the exception of the lateral incisors in the mandible. Figure 2 shows altered incisor tooth shape in a 19-year-old male with WS.

Only one individual had a taurodontic mandibular 1st molar (2.5% of the individuals). When assessing mandibular 2nd molars, the prevalence increases to 38.5% (10 individuals out of 26), or a prevalence of 26.9% when considering 2nd mandibular molars as the dependent variable.

There was no tendency towards more taurodont teeth in those individuals with hypodontia, as only 4 out the 11 individuals with taurodontic teeth had agenesis of any permanent tooth.

When considering the total length of the mandibular

Table 2. Mesio-distal dimensions in mm of maxillary and mandibular teeth in females

	Present study			Townsend, 1983			
	No. of teeth	Mean	*s*	No. of teeth	Mean	*s*	Significance
Maxilla							
Central incisor	35	7.64	0.57	95	8.69	0.52	***
Lateral incisor	34	5.85	0.42	82	6.70	0.54	***
Cuspid	34	7.13	0.48	53	7.71	0.35	***
1st premolar	30	6.49	0.58	53	6.94	0.35	***
2nd premolar	22	6.30	0.64	55	6.61	0.36	*
1st molar	33	10.03	0.58	82	10.37	0.51	**
2nd molar	13	9.04	0.69	35	10.02	0.64	***
Mandible							
Central incisor	30	4.81	0.38	94	5.42	0.31	***
Lateral incisor	36	5.27	0.35	93	5.99	0.36	***
Cuspid	36	6.14	0.44	58	6.64	0.32	***
1st premolar	33	6.37	0.54	54	7.03	0.37	***
2nd premolar	22	6.85	0.58	54	7.03	0.39	n.s.
1st molar	31	10.50	0.41	58	10.95	0.64	***
2nd molar	20	9.50	0.61	39	10.52	0.69	***

s = standard deviation.
n.s. = not significant; *significant at $P < 0.05$; **significant at $P < 0.01$; ***significant at $P < 0.001$.

Table 3. Labio-lingual dimensions in mm of maxillary and mandibular teeth in males

	Present study			Townsend, 1983			
	No. of teeth	Mean	*s*	No. of teeth	Mean	*s*	Significance
Maxilla							
Central incisor	17	6.74	0.58	69	7.30	0.53	***
Lateral incisor	15	6.22	0.73	59	6.50	0.52	n.s.
Cuspid	18	7.74	0.55	64	8.50	0.51	***
1st premolar	14	8.60	0.43	58	9.40	0.52	***
2nd premolar	12	8.92	0.37	67	9.50	0.58	***
1st molar	19	10.65	0.72	83	11.70	0.54	***
2nd molar	15	10.55	0.66	58	11.80	0.71	***
Mandible							
Central incisor	19	5.94	0.55	69	6.20	0.45	n.s.
Lateral incisor	21	6.08	0.57	66	6.40	0.40	*
Cuspid	17	7.08	0.85	59	7.90	0.49	***
1st premolar	17	7.35	0.87	55	8.20	0.52	***
2nd premolar	12	8.11	0.47	63	8.60	0.50	**
1st molar	21	9.82	0.60	80	10.80	0.49	***
2nd molar	14	9.70	0.61	57	10.70	0.58	***

s = standard deviation.
n.s. = not significant; *significant at $P < 0.05$; **significant at $P < 0.01$; ***significant at $P < 0.001$.

molars, we found that most of the teeth categorized as being taurodontic were more than 1 *s* shorter (12 out of 15 taurodontic teeth) compared to the reference values given by Schalk-van der Weide (24). Short total tooth length influences the CB/R ratio and might result in more teeth being categorized as taurodontic without meeting the common definition of taurodontism.

No radiographic signs of invagination of maxillary incisors were seen, but some individuals had a clinically deep palatinal groove. One female individual had a supernumerary incisor in the lower jaw, which was surgically removed at the age of 7 years. One male individual showed extensively calcified pulp chambers of all permanent teeth. No signs of ectopic eruption or retention of maxillary canines were observed.

Discussion

This investigation is part of a systematic study of individuals with WS concerning dental, oral and craniofacial characteristics. The present study has shown that certain dental anomalies, e.g. hypodontia, small tooth crown size, and morphological aberrations of tooth crowns, are common in WS.

Patterns of dental aberrations have been studied in many syndromes and may contribute to the knowledge of etiology of a syndrome and/or the mechanism behind deviations of tooth development in general. When the etiology of a syndrome is known, an indication of the mechanisms behind tooth aberrations can be given. On the other hand, if the etiology of a syndrome is unknown, a

Table 4. Labio-lingual dimensions in mm of maxillary and mandibular teeth in females

	Present study			Townsend, 1983			
	No. of teeth	Mean	*s*	No. of teeth	Mean	*s*	Significance
Maxilla							
Central incisor	35	6.68	0.54	57	7.12	0.50	***
Lateral incisor	34	5.97	0.70	55	6.30	0.49	*
Cuspid	35	7.68	0.57	51	8.11	0.44	***
1st premolar	34	8.18	0.57	53	9.15	0.48	***
2nd premolar	25	8.23	0.77	56	9.16	0.56	***
1st molar	37	10.33	0.63	92	11.35	0.53	***
2nd molar	19	10.25	0.73	44	11.35	0.70	***
Mandible							
Central incisor	26	5.68	0.53	65	5.94	0.41	*
Lateral incisor	29	6.08	0.49	63	6.24	0.41	n.s.
Cuspid	28	6.90	0.70	54	7.43	0.52	***
1st premolar	32	7.17	0.81	55	7.77	0.54	***
2nd premolar	20	7.73	0.63	56	8.39	0.55	***
1st molar	33	9.68	0.51	87	10.46	0.49	***
2nd molar	24	9.47	0.41	44	10.31	0.57	***

s = standard deviation.
n.s. = not significant; *significant at $P < 0.05$; ***significant at $P < 0.001$.

Table 5. Tooth morphology of the maxillary and mandibular central and lateral incisors in Williams syndrome

	Sex	No. of teeth	Scores	
			Normal (%)	Tapered (%)
Maxilla				
Central incisor	Male	23	17.4	82.6
	Female	37	48.6	51.4
Lateral incisor	Male	19	31.6	68.4
	Female	35	45.7	54.3
Mandible				
Central incisor	Male	21	14.3	85.7
	Female	32	40.6	59.4
Lateral incisor	Male	21	52.4	47.6
	Female	37	86.5	13.5

contribution to the knowledge of the etiology can be made using information from the patterns of tooth aberrations. The pattern of hypodontia and tooth crown size can also have diagnostic value (21).

To the authors' knowledge, only Hertzberg et al. (14) and to some extent Fearne et al. (15) have so far comprehensively described the occurrence of different dental anomalies in WS.

This study has enabled us to further demonstrate a relationship between certain dental characteristics and WS. We showed a higher prevalence of hypodontia (40.5%) and oligodontia (11.9%) of permanent teeth in WS than in the general population. Our results are in agreement with Hertzberg et al. (14) and Fearne et al. (15). However, Hertzberg et al. (14) reported the prevalence on hypodontia in 27 individuals with WS who had a mixed or permanent dentition to be only 14.8%. None of the individuals with hypodontia were missing more than one tooth. This is probably an underestimation, since no dental radiographs were taken. Fearne et al. (15) estimated the prevalence of hypodontia in a radiographic study on 27 individuals with WS aged 12 to 41 years to be 22%, but no details were given regarding type of teeth nor the number of missing teeth per individual.

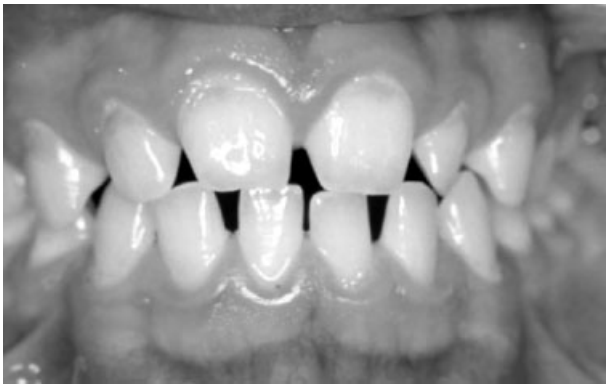

Fig. 2. Clinical photograph showing altered incisor tooth shape (screwdriver shape) in a 19-year-old male with Williams syndrome.

The prevalence of reported hypodontia in normal populations throughout the world varies considerably. The prevalence of hypodontia in the Scandinavian populations has been reported to be between 5% and 10% (for review, see 31). The prevalence of oligodontia, 3rd molars excluded, has only been studied by a few. Using data from studies on hypodontia throughout the world, the prevalence of oligodontia has been calculated by Nordgarden et al. (31) to vary between 0.0 and 0.5%. Reports on the prevalence of oligodontia in schoolchildren from the Nordic countries vary between 0.15% and 0.26% (32). Aasheim & Øgaard (30), using data from the Oslo University Craniofacial Growth Archive, reported the prevalence of oligodontia to be 0.10% in Norwegian children. In a recently published article, Rolling & Poulsen (32) reported the prevalence of oligodontia in Danish schoolchildren to be 0.17%.

Our sample represents about 2/3 of all known individuals with the diagnosis WS in Norway older than 10 years. It could be argued that willingness to participate in a study of dental characteristics in WS is higher if the person or parent/guardian is aware of a dental problem or abnormality. In that case the calculated prevalence of hypodontia and oligodontia could be overestimated, but still significantly larger than the estimated prevalence in the general population.

In this study, the assessment of tooth agenesis on panoramic radiographs was performed only on individuals older than 10 years for several reasons. Firstly, late mineralization of 2nd premolars frequently occurs, especially in boys, which might give a false-positive diagnosis of hypodontia in radiographs. This was clearly demonstrated by Wisth et al. (33), as the prevalence of hypodontia decreased with age in their sample of 7-year-old boys re-examined at 9 years of age. Aasheim & Øgaard (30) reported that 11.3% of the boys showed late mineralization of 2nd premolars between ages 9 and 12 years. Secondly, late mineralization of teeth is often associated with hypodontia and oligodontia, and the mean delay of tooth mineraliation increases with the number of missing teeth (24).

Mandibular and maxillary 2nd premolars were the most frequently missing teeth, followed by maxillary and mandibular 1st premolars, maxillary lateral incisors, mandibular central incisors, and maxillary and mandibular 2nd molars. These findings are surprising as the frequency of agenesis of 1st premolars in both jaws was higher than the frequencies for maxillary lateral incisors and mandibular central incisors as reported in other studies. However, all individuals with agenesis of 1st premolars had oligodontia and agenesis of 2nd premolars. The most frequently observed tooth agenesis pattern within the three groups of teeth (incisors, canines/premolars, and molars) seems to be related to separate paths of innervation of the dentition and thereby a possible explanation for the general pattern of tooth agenesis (34, 35). The teeth close to the nerve stems, which are the first to be innervated, are the first teeth to be formed

(maxillary central incisors, mandibular lateral incisors, canines, and 1st molars). These teeth are also the most stable in relation to agenesis. On the other hand, the teeth more distal to the nerve stem seem to be more influenced in relation to agenesis (maxillary lateral incisors, mandibular central incisors, 2nd premolars, and 2nd/3rd molars). In this study it is shown that both early and late developing teeth were affected. Development of the permanent lateral incisor is initiated in the 5th/6th month of prenatal life, whereas development of the 2nd premolar starts in the 7th/8th month postnatal. This indicates that the tooth agenesis in WS may also be influenced by other genetic factors.

The genetic background for agenesis, size, and morphology of teeth has been the subject of several studies. Because of the short period of formation and constant size after mineralization, teeth are well suited for genetic studies. Numerous different genes have been implicated in tooth development by gene expression in humans and in experimental animal studies, and in theory any of these genes may cause tooth aberrations or agenesis. Two most interesting genes in association with hypodontia are mutations of MSX1 located in chromosome 4 (4p16) and PAX9 located in chromosome 14 (14q21-q13) are identified (36). These genes have not so far been investigated in WS. Based on existing evidence, it is obvious that hypodontia/oligodontia are heterogeneous traits, with the possibility for several mutated genes being responsible. The publications of the human genome sequence (37, 38) are valuable for further studies on WS and the search for possible mutated genes within the WS critical region at chromosome 7 (7q11.23) or in other chromosomes. Combining the results from clinical and genetic studies will be essential in future research.

The present study showed significantly smaller mesio-distal tooth crown size and altered tooth morphology in WS compared with the general population. These findings are in agreement with Hertzberg et al. (14).

To our knowledge, no studies have been performed of labio-lingual dimensions of tooth crowns in WS. From clinical inspection, smaller labio-lingual dimensions could be expected in WS. The present study showed that nearly all teeth were smaller also in the labio-lingual dimension compared to the reference values given by Townsend (25).

Besides smaller tooth crowns, alterations in tooth morphology have been described in individuals with hypodontia and oligodontia (17, 22, 24). In the present study, a high proportion of the maxillary and mandibular incisors were described as tapered or screwdriver-shaped. However, no quantitative information on variation in tooth morphology in normal populations could be found in the literature, so no comparison could be made. Clinically, alterations in tooth crown morphology and reduction in tooth crown size are of importance in relation to dental treatment.

Hertzberg et al. (14) reported 40.7% abnormal incisor morphology in their material of individuals with WS and peg-shaped maxillary lateral incisors were the most common. Thus, the aberrant incisor tooth morphology is an important characteristic of WS. Conical incisors have been described by several authors in relation to hypodontia and oligodontia (24). Bot & Salmon (39) reported a prevalence of 1.59% peg-shaped maxillary lateral incisors in a large adult population. This is higher than was reported by Bäckman & Wahlin (20).

Syndromic and non-syndromic hypodontia/oligodontia have similar associated anomalies, with a tendency towards reduced size, altered morphology, and taurodontism. Variations in criteria, methods employed, and samples of different ethnic background have resulted in great variation in the reported prevalence of taurodontism in normal populations. Jaspers & Witkop (40) suggested an overall prevalence of 2.5% in healthy adult Caucasian populations after reviewing the literature; the mandibular 2nd molar being the most frequently involved tooth in the dentition.

The prevalence of taurodontism of mandibular 1st molars in our study was 2.5%. When calculating the prevalence taurodontism in mandibular 2nd molars this increased to 41.7%. The frequency of taurodontism was thereby considerably higher in mandibular 2nd molars, which is in agreement with other studies (40).

Panoramic radiographs are not ideal for assessing taurodontism using a metric crown-body/root ratio because of radiographic magnification and distortion in the vertical dimension. However, these were the only dental radiographs available. It was considered ethically unacceptable to expose the patients to further radiation for the sole purpose of making a measurement of length of teeth. In this study, measuring tooth total lengths showed that some of the mandibular molars were short. Assessment of taurodontism is difficult in teeth with reduced total tooth lengths and the results should therefore be interpreted with caution.

In older reports the presence of dental carious lesions in individuals with WS is mentioned, but dental caries can hardly be considered a characteristic of a syndrome. A possible increased prevalence in dental caries might be a result of a combination of enamel hypoplasia/enamel hypomineralization and a low degree of preventive oral health. In our study, very few individuals had carious lesions or dental restorations, and enamel hypoplasia and enamel hypomineralization was only found sporadically in few individuals. The level of oral hygiene was high and most of the younger individuals had been included in expanded individual oral health care programmes within the Community Dental Health Services.

Conclusions

It can be concluded that there is a high prevalence of tooth agenesis in WS, and that a large proportion has agenesis of more than 6 teeth. The majority of individuals with WS have small permanent teeth, both in the mesio-distal and labio-lingual dimensions, and some tooth groups, espe-

cially incisors in both jaws, have a tapered or screwdriver shape. Thus, hypodontia, small tooth crown size and certain morphological traits are parts of WS.

Hypodontia or oligodontia in combination with small tooth size and alterations in tooth morphology may affect dental esthetics and complicate orthodontic and/or prosthodontic treatment. It is therefore important that all individuals with WS are offered a dental examination and enrolled in a preventive oral health-care program at an early age.

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