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Original Article

Mesio-distal Tooth Angulation in Elderly with Many Remaining Teeth Observed by 3-D Imaging

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Abstract

Few studies have investigated the morphologic characteristics of teeth, dental arches and occlusion in elderly persons with many remaining teeth. The purpose of this study was to establish a method of measurement using 3-D imaging to investigate tooth angulation in the elderly from the orthodontic point of view. The dental casts of 20 elderly persons with many remaining teeth were digitized with a 3-D laser scanner (VMS-100F, UNISN INC., Osaka, Japan) to construct 3-D images. The mesio-distal angulation of each tooth was then measured with analytical software (SURFLACER, UNISN INC. and IMAGEWARE 12, UGS PLM Solutions, MO, USA). The occlusal plane formed by the incisal edge of the central incisor and distal buccal cusp tip of the first molar on either side was used as a reference plane for measurements. Mesio-distal tooth angulation (indicated in degrees) of maxillary teeth in this subjects averaged 1.26 for central incisors, 5.46 for lateral incisors, 7.84 for canines, 6.59 for first premolars, 5.78 for second premolars, 1.64 for first molars and −4.17 for second molars. Average values for mandibular teeth were 0.91 for central incisors, 2.35 for lateral incisors, 7.04 for canines, 8.76 for first premolars, 10.44 for second premolars, 7.33 for first molars and 12.67 for second molars. There was no statistical difference between the data in man and women except maxillary second molar ($p<0.05$). Mesial angulation in the mandibular arch showed a progressive increase from the anterior to the posterior. However, this tendency was not observed in the maxillary arch.

Key words: Tooth angulation—Elderly with many remaining teeth—Dental cast—3-D images—Crowding

Introduction

Eighty-twenty (8020) is the slogan of a campaign by the Japan Dental Association and Ministry of Health and Welfare to promote oral health not only in elderly people, but also

in the younger generation. An "8020 achiever" is anyone who has more than 20 remaining teeth at the age of 80 years or over. According to a report by the Ministry of Health and Welfare in 1989, at the onset of this campaign, only 8% of this population group could be categorized as 8020 achievers, with an average number of 4.5 present teeth. However, by 2005, this percentage had increased to 20%, with an average of 10 remaining teeth.

The Japan Dental Association marked the first 10 years since the inception of the 8020 campaign by gathering the results of anatomical studies on dentition in the elderly, issuing a report in 1999[16]. The results showed that the campaign had improved occlusion and contained much information on trends in dentistry in this age group.

Andrews[1] reported tooth angulation in non-orthodontic normals for application of the "Straight Wire Appliance", which is a kind of multi-bracket system. In their study, a bracket slot was cut under each tooth for measurement of angulation inclination and arch form. In a later similar study, Sebata[17] measured them in non-orthodontic Japanese with a profile projector. These studies recommended the Straight Wire Appliance, but did not discuss whether angulation was viable long-term. Naturally, knowledge of anatomy in the elderly is necessary for practical dentistry.

From the mechanical point of view, Tokuda[19] investigated the influence of occlusal contact on displacement. The displacement paths of maxillary left first molars in patients in good general health were measured using a Type-3 tooth displacement transducer. The results showed that, when occlusal contact in the buccal cusp was displaced in the mesio-buccal direction, a wide dental arch and a slight discrepancy were generated at the distal interproximal contact area of the teeth. Miura [14] observed horizontal tooth displacement and the behavior of inter-dental proximal contact in relation to function. The movement of the maxillary and mandibular left molars was measured by a transducer. The maxillary molars showed displacement in the disto-lingual direction, while the mandibular molars showed displacement in the mesio-lingual direction. Displacement of the mandibular molars in the mesio-distal direction was less than that of the maxillary molars. Although the patients in these reports were of the younger generation, the results indicated that occlusal force had the potential to cause tooth movement.

Table 1 Characteristics of the subject

	Number	Age		Present teeth	
		Mean	SD	Mean	SD
Men	10	81.4	1.9	28.1	1.7
Women	10	83.3	2.9	28.5	1.9
Total	20	82.3	2.6	28.3	1.8

The hypothesis of the research was that tooth angulation would change with age for these reasons. As a first step, we established a method of measurement using a 3-D computer system to determine mesio-distal tooth angulation in the elderly.

Methods

Twenty elderly with many remaining teeth (10 men, 10 women; average age, 82 years; average number of teeth, 28.3) were selected from among approximately 300 elderly persons participating in the "8020 Campaign" in Tokyo and Chiba, Japan (Table 1). In order to participate in the study, all patients had to fulfill the following criteria: no orthodontic treatment, very few missing teeth, good occlusion, no TMD symptoms and a good profile. Dental casts were used to evaluate dental condition, including overjet, overbite, molar relationship and crowding. Some of the data was obtained with an automatic caliper (Mitutoyo, Co., Kawasaki, Japan). A vertical relationship of occlusion of more than 4 mm of overbite was classified as deep bite, with 0–4 mm as normal and less than 0 mm as open bite. An anterior-posterior relationship of occlusion of more than 4 mm of overjet was classified as maxillary protrusion, with 0–4 mm as normal and less than 0 mm as mandibular protrusion.

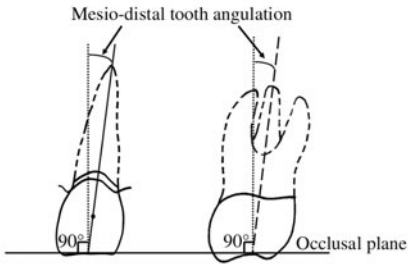

Fig. 1 Mesio-distal tooth angulation
Mesio-distal tooth angulation is a complementary angle, where the long axis of the clinical crown (long dots) is measured from a line at 90 degrees to the occlusal plane.

Overlapping of teeth of more than 3 mm was classified as crowding[10,15,16,18].

The occlusal plane of the dental casts formed by the incisor edge of the central incisor and distal buccal cusp tip of the first molar on either side was used as a reference plane for measurement of the mesio-distal angulation of each tooth. Tooth angulation is a complementary angle, where the long axis of the clinical crown is measured from a line at 90 degrees to the occlusal plane (Fig. 1). The dental casts were digitized with a 3-D laser scanner (VMS-100F, UNISN INC., Osaka, Japan) to construct 3-D images[5,8,9] (Fig. 2). Mesio-distal angulation in each tooth was then measured with analytical software (SURFLACER, UNISN INC. and IMAGEWARE 12, UGS PLM Solutions, MO, USA).

Measuring method of mesio-distal angulation of tooth (Figs. 3–7):

1. The deepest point of the tooth cervical curve was marked and a line made to indicate crown width and the central point of crown width. Next, the deepest point of the cervical curve and the central point of the crown width were connected. The tooth axis (Yellow line) was then determined (Fig. 3).

2. A line was drawn parallel to the line indicating width between tooth contact points and this was termed the copied line (Pink line), and a vertical line was set connecting the two lines at a right angle to both (Fig. 4).

3. The central point of the copied line was selected as marking the location of the vertical plane (Red plane, Fig. 5).

4. The Red plane was set at a right angle vertically to the occlusal plane. The Green plane was set at a right angle vertically to the Red plane, facing the labial or buccal surface of the crowns (Green plane). The Yellow tooth axis line was changed to the Blue line after being projected to the Green plane (Fig. 6). Tooth angulation was measured between the Blue line and the Red line (or plane, Fig. 7). A plus value indicated mesial angulation and a minus value indicated distal angulation.

Results

In terms of occlusal status, overjet was more than 4-mm in 28.4%, 1–4 mm in 71.6%, and negative with anterior crossbite in 0%, whereas overbite was deeper than 4-mm in 25%, 1–4 mm in 75%, and negative with anterior open bite in 0%. An Angle's Classification of Class I was seen in 65%, while Class II occupied 35% and Class III occupied 0%. In terms of maxillary crowding, 5.2% had crowding, while mandibular crowding was seen in 48.9%. The average value for maxillary crowding was −0.5 mm, and mandibular crowding was −2.85 mm ($p<0.001$).

Mesio-distal tooth angulation (indicated in degrees) in the maxillary teeth averaged 1.26 for central incisors, 5.46 for lateral incisors, 7.84 for canines, 6.59 for first premolars, 5.78 for second premolars, 1.64 for first molars and −4.01 for second molars. Average values for the mandibular teeth were 0.91 for central incisors, 2.35 for lateral incisors, 7.04 for canines, 8.76 for first premolars, 10.44 for second premolars, 7.33 for first molars and 12.67 for second molars. There were no sex-related statistically significant differences except maxillary second molar ($p<0.05$, Tables 2, 3).

Discussion

Meredith[12] defines growth as "the entire series of anatomic and physiologic changes

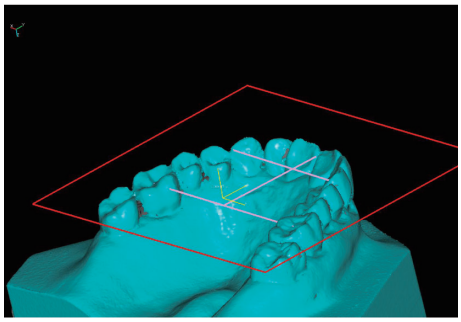

Fig. 2 Digitizing the dental cast
The dental casts were digitized with a 3-D laser scanner to construct 3-D images.

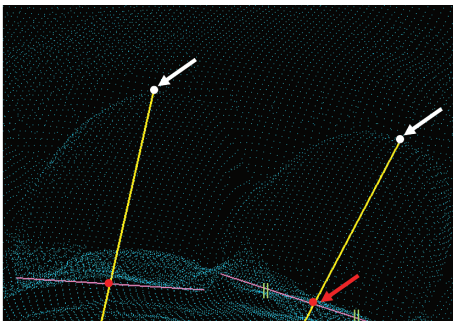

Fig. 3 Yellow line represents tooth axis
Deepest point of the tooth cervical curve (White arrow) and the central point of crown width (Red arrow) were marked. Next, the deepest point of the cervical curve and the central point of the crown width were connected. The tooth axis (Yellow line) was then determined.

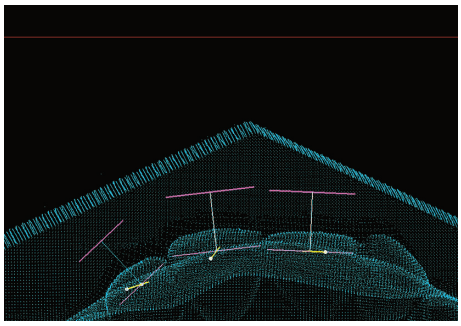

Fig. 4 Pink line represents copied line
A line was drawn parallel to the line indicating width and this was termed the copied line (Pink line), and a vertical line was set connecting the two lines at a right angle to both.

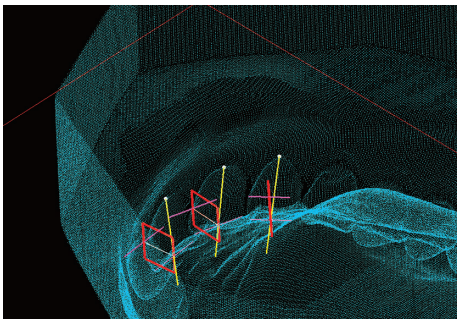

Fig. 5 Red plane represents vertical plane to occlusal plane (weak red line)
The central point of the copied line was selected as marking the location of the vertical plane (Red plane) which was vertical to the occlusal plane.

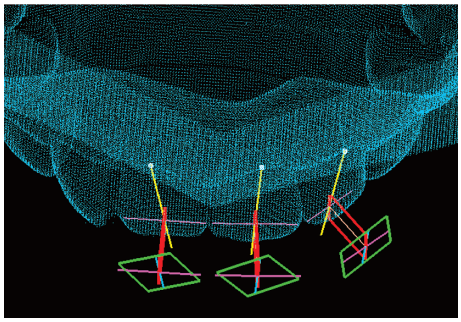

Fig. 6 Green plane is vertical to Red plane
Red plane was set at a right angle vertically to the occlusal plane. Green plane was set at a right angle vertically to Red plane, facing the labial or buccal surface of the crowns. Yellow tooth axis line was changed to Blue line after being projected to Green plane.

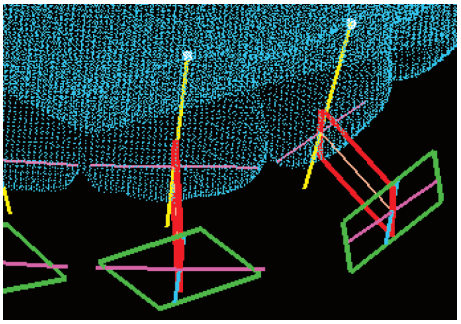

Fig. 7 Mesio-distal tooth angulation
Mesio-distal tooth angulation was measured between Blue line and Red line (or plane).

Table 2 Results of mesio-distal tooth angulation of the subjects

	Man (10)		Women (10)		Total (20)		*t*-test M×W
	Mean	SD	Mean	SD	Mean	SD	
Maxillary							
Central incisor	0.80	3.08	1.72	3.79	1.26	3.44	n.s.
Lateral incisor	4.29	5.91	6.61	4.96	5.46	5.44	n.s.
Canine	8.25	5.67	7.43	6.37	7.84	6.02	n.s.
First premolar	6.49	5.48	6.68	5.36	6.59	5.42	n.s.
Second premolar	4.75	5.03	6.81	5.43	5.78	5.23	n.s.
First molar	1.80	4.95	1.47	5.85	1.64	5.40	n.s.
Second molar	−1.55	6.79	−6.46	7.40	−4.17	7.10	*
Mandibular							
Central incisor	0.51	5.07	1.30	10.18	0.91	7.63	n.s.
Lateral incisor	1.68	4.83	3.02	7.10	2.35	5.97	n.s.
Canine	6.70	7.98	7.37	6.04	7.04	7.01	n.s.
First premolar	8.90	7.45	8.61	6.60	8.76	7.03	n.s.
Second premolar	11.09	6.85	9.79	7.21	10.44	7.03	n.s.
First molar	6.50	8.22	8.16	8.25	7.33	8.24	n.s.
Second molar	9.95	13.28	16.69	9.77	12.67	11.26	n.s.

*: $p<5\%$, n.s.: non significant difference

Table 3 Results of this research, Andrews[1,3] and Sebata[17]

	Fuma	Sebata	Andrews
Maxillary			
Central incisor	1.26	4.25	3.59
Lateral incisor	5.46	5.74	8.04
Canine	7.84	7.74	8.40
First premolar	6.59	3.51	2.70
Second premolar	5.78	6.18	2.82
First molar	1.64	5.22	5.70
Second molar	−4.17	−0.30	0.40
Mandibular			
Central incisor	0.91	−0.48	0.53
Lateral incisor	2.35	−1.20	0.38
Canine	7.04	1.48	2.50
First premolar	8.76	2.52	1.30
Second premolar	10.44	6.70	1.54
First molar	7.33	5.74	2.00
Second molar	12.67	7.34	2.90

taking place between the beginning of prenatal life and the close of senility". It is essential to know the anatomical and physiologic characteristics of each generation. The average life of expectancy of Japanese people is over 80 years. Knowledge of dentition in elderly persons with many remaining teeth is important for many branches of dentistry. In particular, such knowledge is essential in achieving long-term stability and planning orthodontic treatment for the elderly. The elderly participants in this study all had more than 28 teeth, allowing us to make anatomical measurements. Above all, 3-dimensional evaluation is very important for diagnosis, treatment planning and prognosis after retention. To the authors' knowledge, no other studies have been published on the 3-dimensional evaluation of mesio-distal tooth angulation.

Earlier studies focused on participants with normal occlusion[1,3,17], so this was one of the criteria for participation in this study, too. None of the subjects in this study had anterior crossbite or open bite. The molar relationship in the participants revealed Class I or Class II, overjet (horizontal relationship between anterior maxillary incisor and mandibular incisor) or overbite (vertical relationship between anterior maxillary incisor and mandibular incisor), indicating that elderly persons with many remaining teeth have almost normal occlusion.

As far as crowding is concerned, a tendency toward crowding in the mandibular arch was observed. The average value for maxillary crowding was −0.5 mm and the average for mandibular crowding was −2.85 mm ($p<0.01$).

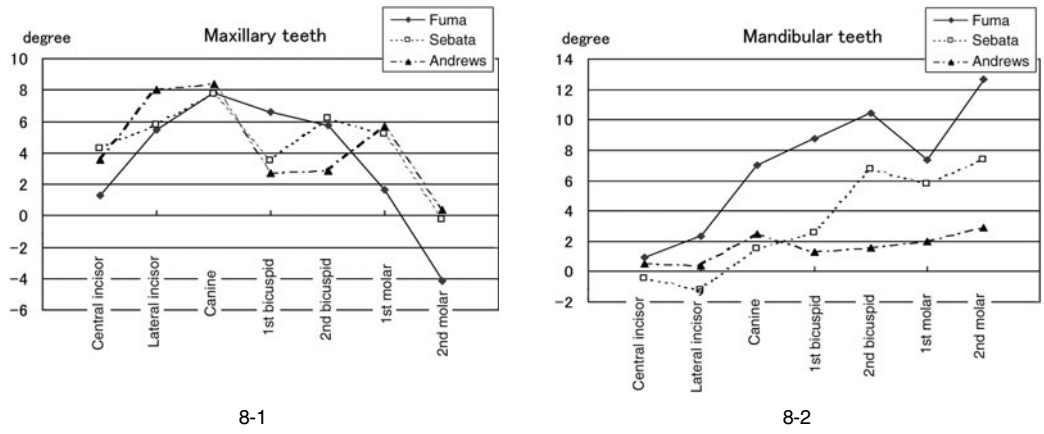

Fig. 8 Comparison mesio-distal angulation of this study with those of Andrews[1,3] and Sebata[17]
8-1: Maxillary teeth, 8-2: Mandibular teeth.

Mishima[13] reported mandibular crowding and loss of occlusal height in canine and second molars after long-term observation. Orthodontists have noted the prevalence of mandibular crowding in post-treated patients[11]. However mandibular crowding was also seen in the non-orthodontic elderly subjects in this study. This suggests that crowding will occur with time especially in mandibular arch[6], regardless of orthodontic treatment[4].

In this study, the dental casts were digitized with a 3-D laser scanner (VMS-100F) to construct 3-D images according to the method of earlier studies[5,8,9]. The image is composed of dots, termed a "cloud", and is easy to expand to confirm reference points or lines. Two-dimensional or 3-dimensional analyses from any direction can be done using the analytical software employed here (SURFLACER and IMAGEWARE 12). This method may be viewed as a kind of 2-dimensional measurement using 3-dimensional images, which we employed so as to conform to the methods of Andrews[1,3] and Sebata[17] as much as possible (Figs. 3–7). In Sebata's method[17], a line of tooth angulation on the labial or buccal surface of the plaster model is drawn. The model is then cut into 6 small blocks in order to face the labial or buccal surface to the screen of a profile projector. Tooth angulation and the occlusal plane are traced onto tracing paper, and the lines are plotted with an x-y plotter. Finally, angulation is measured by a computer. With this method, however, it is difficult to measure many anatomical positions such as angle or distance as the plaster model has be split up into small segments. This was the reason a 3-D procedure was used in this study. The 3-dimensional images used in our analysis offer the potential for further observations such as tooth inclination, tooth rotation, tooth wear and arch form.

It was found that the difference between men and women in maxillary second molar angulation. Behrents[2] found in female the molars tend to become distally inclined and showed a significant gender difference in the molar configuration in his longitudinal study with cephalogram. West and McNamara[20], however, examined that molars in both genders erupted and moved mesially during adulthood. According to experimental report[19], the maxillary molars were shifted in the disto-palatal direction and the mandibular molars in the mesio-lingual direction. In this study, too, the maxillary second molars exhibited distal angulation while the mandibular molars showed mesial angulation. Progressive mesial angulation, in particular, was revealed in the mandibular teeth from the anterior to the posterior.

Figure 8 shows a comparison between this

study and those of Andrews[1] and Sebata[17]. The participants in the Andrews study were non-orthodontic Americans with healthy dentition, and those in the Sebata study were similar Japanese. In both studies, the participants were young adults. Although it is impossible to compare them directly, it is possible to compare tendencies: mandibular tooth angulation in this study showed a tendency toward higher mesial angulation than in the other two studies. This suggests that progressive mesial angulation in the mandibular teeth affects the alignment of the mandibular anterior teeth. In other words, it leads to mandibular crowding. The measuring tool used by Andrews was a kind of caliper, while Sebata used a profile projector and caliper. Therefore, it should be possible to compare values in young adults with 3-D images.

Kaneko *et al.*[10] reported that cervical lesions were observed more often in the maxillary teeth than in the mandibular teeth, with the difference statistically. Fukuda[7] compared dental casts in 15 human adults with apparently normal occlusion at 20 and 40 years of age with regard to occlusal facets and occlusal contact in the intercuspal position of the posterior teeth. Both theoretical frequency and the area of occlusal facets showed a tendency to increase with aging in the first and second premolars. If occlusal force is a cause of cervical lesions, mesial angulation in the mandibular teeth may serve as a kind of buffer to strong and continuous occlusal force.

Twenty elderly participants with many remaining teeth and almost normal occlusion took part in this study, allowing measurements to be taken. Their dental casts were digitized with a 3-D laser scanner to construct 3-D images. Mesio-distal angulation in each tooth was then measured to clarify tooth angulation in the elderly. Mesial angulation in the mandibular arch showed a progressive increase from the anterior to the posterior. However, this tendency was not observed in the maxillary arch.

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