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Original Article

Model Analysis in "8020" Achievers Using Three-dimensional Images

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Abstract

The purpose of this study was to clarify the effect of aging on the dentition by quantifying the dimensions of the dental arches in elderly persons aged over 80 years with 20 or more remaining teeth (8020 achievers). The study included twenty 8020 achievers (10 males and 10 females, with an average age of 82.3 years and an average of 28.3 present teeth). Their dental casts were digitized with a 3-dimensional (3-D) laser scanner, reconstructed into 3-D images, and measured with IMAGEWARE. The anterior and posterior widths of the upper and lower coronal arches and their anterior and posterior lengths together with the anterior and posterior widths of the maxillary and mandibular basal arches and their anterior and posterior lengths were measured. An unpaired *t*-test was performed using statistical analysis software. Dental models of 31 people with normal occlusion (16 males and 15 females, with an average age of 23.3 years) were measured with digital calipers and compared with the measurements obtained from the 8020 achievers. Several common items with significant differences were observed in the mandibular measurements. Each comparison indicated a tendency toward a decrease in size in the 8020 group: Coronal Arch P-length ($p<0.05$ in Male group, $p<0.01$ in Female group), Basal Arch A-width ($p<0.05$ in Male group, $p<0.001$ in Female group), Basal Arch A-length ($p<0.001$ in both group), and Basal Arch P-length ($p<0.001$ in both group). From these results, 3-D dental model analysis in twenty 8020 achievers revealed narrowing of the mandibular intercanine width and shortening of the mandibular anterior and posterior lengths.

Key words: Model analysis — Elderly with many remaining teeth — 3-D images — Dental cast

Table 1 Characteristics of subjects

8020 achievers	Number	Age		Present teeth		Normal occlusion	Number	Age		Present teeth	
		Mean	SD	Mean	SD			Mean	SD	Mean	SD
Male	10	81.4	1.9	28.1	1.7	Male	16	23.9	2.1	29.2	1.5
Female	10	83.3	2.9	28.5	1.9	Female	15	22.7	0.8	28.5	1.9
Total	20	82.3	2.6	28.3	1.8	Total	31	23.3	1.7	28.8	1.2

Introduction

Epidemiological studies on the relationship between oral health and general health conducted in elderly populations have revealed that chewing ability was most strongly associated with the number of present teeth. It has also been shown that elderly persons aged over 80 years with 20 or more remaining teeth (8020 achievers) have high chewing ability and good general health status. Changes in the teeth, dental arches, and jawbones with age have been investigated in 8020 achievers as a model of healthy aging to identify factors contributing to general health[1,7,8,12,14–16,18].

Several longitudinal studies have looked at changes in the dimensions of the dental arch such as arch width, arch length, irregularity index, overjet and overbite using dental casts[2–4,6,9,10,13,19,21]. Dager *et al.*[6] reported changes in dental arch dimensions in a longitudinal study involving 20 males and 20 females with normal occlusion over a period of 40 years and an average age of 17 to 58.4 years. Their results showed little change in overjet or overbite and a slight increase in the mandibular anterior irregularity index. Bishara *et al.*[2,3] observed that the intercanine and intermolar widths and arch length decreased between 26 and 45 years of age in studies evaluating dento-alveolar changes in 15 males and 15 females with normal occlusion. Mishima[13] analyzed dental casts obtained from 23 males and 4 females with normal occlusion and aged between 20 and 40 years. The results showed small increases in overjet and overbite, proclination and elongation of the maxillary incisors with increased spacing, and an increase in mandibular anterior crowding, suggesting that these age-related changes occurred spontaneously to adjust for occlusal interference, premature occlusal contacts, and excessive occlusal stress.

We had the opportunity to perform a three-dimensional (3-D) analysis of dental casts obtained from 8020 achievers as part of our 8020 research program. We thought that a study comparing the dental arches of octogenarians with those of younger individuals would provide useful information on long-term dimensional changes in the dental arches, although this was not a longitudinal study. The purpose of this study was to explore age-related changes in the dimensions of the dental arch by analyzing 3-D images of dental casts obtained from 8020 achievers and compare the results with those for people in their 20's with normal occlusion.

Methods

1. Subjects (Table 1)

The study sample comprised twenty 8020 achievers (10 males, 10 females, average age 82.3 years, average number of 28.3 remaining teeth). On oral examination, sound teeth, restored teeth, and unrestored teeth were classified as present teeth, while missing teeth, congenital or otherwise, were categorized as lost teeth.

The study also included a group of 31 individuals with normal occlusion (16 males, 15 females, average age 23.3 years, average number of 28.8 remaining teeth) whose dental casts are archived in the Orthodontic Department of Tokyo Dental College. Eligibility criteria for inclusion in the normal occlusion

group were Class I molar relationship, absence of restorations, overjet of 2–4 mm, overbite of 2–4 mm, and mandibular anterior crowding of more than −4 mm. (Kaneko *et al.*[12])

2. Methods of measurement

Dental casts obtained from twenty 8020 achievers were digitized with a 3-D laser scanner (VMS-100F, UNISN Inc., Osaka, Japan), reconstructed into 3-D images, and 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 tips of the first molars was used as a reference plane for model analysis (Fig. 1)[5,7,8,11,17,19].

The anterior and posterior widths of the maxillary and mandibular coronal arches and their anterior and posterior lengths together with the anterior and posterior widths of the maxillary and mandibular basal arches and their anterior and posterior lengths were measured using the above-defined occlusal plane as a reference.

1) Coronal Arch (Fig. 1)

(1) Length

Anterior length (A-length): anteroposterior distance from the mesial contact point of the central incisor to the line connecting the distal contact points of the canines.

Posterior length (P-length): anteroposterior distance from the mesial contact point of the central incisor to the line connecting the central pits of the molars.

(2) Width

Anterior width (A-width): transverse distance between the distal contact points of the canines.

Posterior width (P-width): transverse distance between the central pits of the first molars.

2) Basal Arch (Figs. 2, 3-A, 3-B)

(1) Length

Anterior length (A-length): anteroposterior distance from the most recessed point of the mucobuccal fold of the central incisor root to the line connecting the distal contact points of the canines, measured parallel to the occlusal plane.

Posterior length (P-length): anteroposterior distance from the most recessed point of the mucobuccal fold of the central incisor root to the line connecting the central pits of the first molars, measured parallel to the occlusal plane.

(2) Width

Anterior width (A-width): transverse distance between the deepest points of the mucobuccal folds *via* the distal contact points of the canines on a plane perpendicular to the occlusal plane.

Posterior width (P-width): transverse distance between the deepest points of the mucobuccal folds *via* the buccal pits of the first molars on a plane perpendicular to the occlusal plane.

A digital caliper (Mitutoyo, Co., Kawasaki, Japan) and Ootsubo's measuring device (YDM, Co., Tokyo, Japan) were used to make the same measurements on the dental casts obtained from the 10 male 8020 achievers. The results showed no significant difference in the measurements made with 3-D images and those obtained with the caliper (Table 2).

The dental casts of the 31 adults with normal occlusion archived in the Orthodontic Department of Tokyo Dental College were also measured for similar measurement items using the digital caliper (Mitutoyo, Co.) and Ootsubo's measuring device (YDM, Co.) to compare with the 3-D measurements of the 8020 achievers.

Results

1. Intraoral status in the 8020 achievers

The average number of present teeth, including third molars, was 28.4 (97.3%). The retention rate by tooth type in the maxillary arch was 100% for the lateral incisor, canine, first premolar, and second premolar, followed by 97.5% for the central incisor and first molar, and 82.5% for the second molar. The retention rate in the mandibular arch was 100% for the lateral incisor and canine, 97.5% for the central incisor, first premolar, second

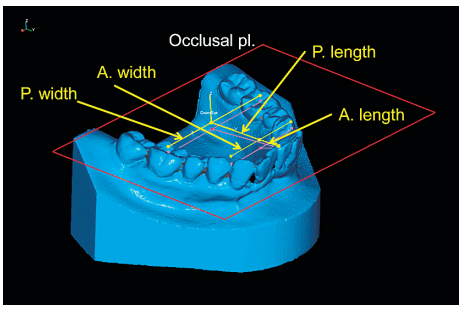

Fig. 1 Measurements of coronal arch

Red plane: Occlusal plane as defined by incisor edge of central incisor and distal buccal cusp tip of first molar was used as reference plane for measurement of 3-D images. Pink point: Distal contact points of left and right canines and central fossa of first molars. Yellow point: Projected to occlusal-plane pink points. Yellow line: Anteroposterior distance from mesial contact point of central incisor to line connecting distal contact points of canines (Anterior length). Anteroposterior distance from mesial contact point of central incisor to line connecting central pits of molars (Posterior length). Transverse distance between distal contact points of canines (Anterior width). Transverse distance between central pits of first molars (Posterior width).

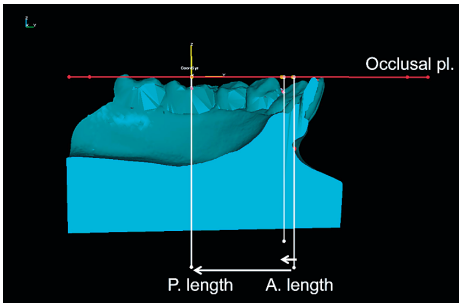

Fig. 2 Measurements of basal arch length

White line: Anteroposterior distance from most recessed point of mucobuccal fold of central incisor root to line connecting distal contact points of canines, measured parallel to occlusal plane (Anterior length). Anteroposterior distance from most recessed point of mucobuccal fold of central incisor root to line connecting central pits of first molars, measured parallel to occlusal plane (Posterior length).

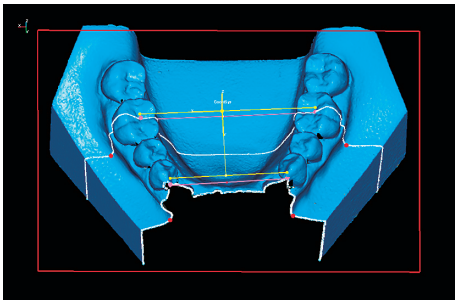

Fig. 3-A Measurement of anterior width in basal arch

White line: Transverse distance between deepest points of mucobuccal folds (red point) *via* distal contact points of canines on plane perpendicular to occlusal plane (red plane).

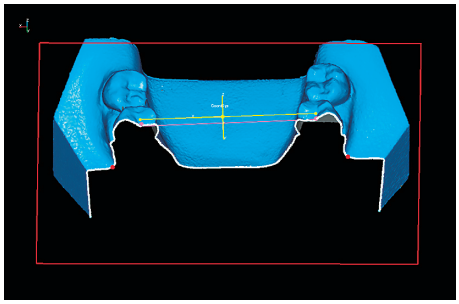

Fig. 3-B Measurement of posterior width in basal arch

White line: Transverse distance between deepest points of mucobuccal folds (red point) *via* buccal pits of first molars on plane perpendicular to occlusal plane (red plane).

Table 2 Results of measurements performed with digital calipers and those of 3-D images in 8020 achievers (male)

		3-D image (n = 10)		Digital calipers (n = 10)		
		Mean	SD	Mean	SD	*t*-test
Maxillary Arch	Coronal Arch A-width	37.67	1.79	37.78	1.63	n.s.
	Coronal Arch P-width	50.50	3.54	50.49	3.24	n.s.
	Coronal Arch A-length	12.26	1.97	12.83	2.18	n.s.
	Coronal Arch P-length	30.51	2.89	30.68	3.12	n.s.
	Basal Arch A-width	42.77	5.52	43.80	3.91	n.s.
	Basal Arch P-width	65.85	3.20	66.04	2.73	n.s.
	Basal Arch A-length	7.51	2.48	7.22	2.33	n.s.
	Basal Arch P-length	25.71	2.73	25.41	2.60	n.s.
Mandibular Arch	Coronal Arch A-width	30.01	2.28	30.01	2.32	n.s.
	Coronal Arch P-width	44.55	3.91	44.42	3.58	n.s.
	Coronal Arch A-length	8.03	1.44	8.17	1.40	n.s.
	Coronal Arch P-length	26.12	2.30	26.29	2.22	n.s.
	Basal Arch A-width	30.00	4.77	31.60	3.86	n.s.
	Basal Arch P-width	62.41	3.46	62.25	3.51	n.s.
	Basal Arch A-length	2.47	2.01	2.28	1.77	n.s.
	Basal Arch P-length	20.78	2.82	20.62	2.59	n.s.

(Unit: mm)

n.s.: non-significant difference

Table 3 Results of oral examination in 8020 achievers

	Tooth type (Both type)	Sound teeth	Filled teeth	Decayed teeth	Missing teeth with prostheses	Missing teeth without prostheses	Present teeth	Missing teeth	Present teeth/Total ×100 (%)
Maxillary teeth	1	22	17	0	1	0	39	1	97.5
	2	28	12	0	0	0	40	0	100
	3	27	12	1	0	0	40	0	100
	4	31	9	0	0	0	40	0	100
	5	28	12	0	0	0	40	0	100
	6	20	19	0	0	1	39	1	97.5
	7	13	19	1	0	7	33	7	82.5
	8	7	5	1	—	—	13	—	—
Mandibular teeth	1	38	1	0	1	0	39	1	97.5
	2	39	1	0	0	0	40	0	100
	3	40	0	0	0	0	40	0	100
	4	29	10	0	1	0	39	1	97.5
	5	24	15	0	0	1	39	1	97.5
	6	14	23	2	1	0	39	1	97.5
	7	15	16	2	0	7	33	7	82.5
	8	7	6	2	—	—	15	—	—
Total		382	177	9	4	16	568	20	97.3
Average		19.1	8.9	0.5	0.2	0.8	28.4	1.0	
Percentage (%)		65.0	30.1	1.5	0.7	2.9	96.6	3.4	

Present teeth = Sound teeth + Filled teeth + Decayed teeth
Missing teeth = Missing teeth with prostheses + Missing teeth without prostheses

premolar, and first molar, and 82.5% for the second molar. The average numbers of sound, restored, and unrestored teeth were 19.1 (65.0%), 8.9 (30.1%), and 0.5 (1.5%), respectively. The average number of lost teeth was 1.0 (3.4%) (Table 3).

Table 4 Vertical relationship between maxillary and mandibular incisors

Overbite	Deep bite 4 mm>	Normal 1–4 mm	Open bite <0 mm	Total
Male	n = 3	n = 7	0	n = 10
Female	n = 2	n = 8	0	n = 10
Total	n = 5	n = 15	0	n = 20
Percentage (%)	25%	75%	0%	100%

Table 5 Antero-posterior relationship between maxillary and mandibular incisors

Overjet	Maxillary protrusion 4 mm>	Normal 1–4 mm	Mandibular protrusion <0 mm	Total
Male	n = 3	n = 7	0	n = 10
Female	n = 2	n = 8	0	n = 10
Total	n = 5	n = 15	0	n = 20
Percentage (%)	25%	75%	0%	100%

Table 6 Percentage of molar relationship and canine relationship

	Molar		Canine	
	Male	Female	Male	Female
Class I	70.0	60.0	60.0	50.0
Class II	20.0	40.0	30.0	50.0
Class III	10.0	0.0	10.0	0.0
Total (%)	100.0	100.0	100.0	100.0

The amount of overbite was larger than 4 mm in 25% and 1–4 mm in 75% (Table 4). The amount of overjet was greater than 4 mm in 25% of the 8020 achievers and 1–4 mm in 75%. No crossbite or open bite was observed (Table 5). Class I, II, and III molar relationships accounted for 65, 35, and 5%, respectively (Table 6). The amount of maxillary anterior crowding was above −3 mm in 75% of the subjects and −3 mm or below in 0%. The remaining 25% exhibited maxillary anterior spacing (Table 7). Mandibular anterior crowding of less than −3 mm and −3 mm or greater were seen in 60 and 35%, respectively (Table 8). The average amount of maxillary anterior crowding was −0.25 mm, and that of mandibular anterior crowding was −2.03 mm.

2. Arch dimensions

The male 8020 achievers showed smaller values for all measurements, except maxillary Basal Arch P-width, mandibular Coronal Arch P-width, and mandibular Basal Arch P-width, than the males with normal occlusion. Maxillary Basal Arch A-length was significantly smaller ($p<0.05$) in the male 8020 achievers than in their normal occlusion counterparts. In the mandibular arch, the 8020 achievers showed significantly smaller Coronal Arch P-length and Basal Arch A-width, at a 5% level ($p<0.05$), and significantly smaller Basal Arch A-length and Basal Arch P-length, at a 0.1% ($p<0.001$) (Table 9).

In the maxillary arch, the female 8020 achievers exhibited significantly smaller Coronal Arch A-width and Coronal Arch P-length,

Table 7 Percentage of crowding in maxillary incisors

	Male	Female	Total
Normal (>−3 mm)	70.0	80.0	75.0
Crowding (≤−3 mm)	0.0	0.0	0.0
Spacing	30.0	20.0	25.0
Total (%)	100.0	100.0	100.0

Table 8 Percentage of crowding in mandibular incisors

	Male	Female	Total
Normal (>−3 mm)	60.0	60.0	60.0
Crowding (≤−3 mm)	40.0	30.0	35.0
Spacing	0.0	10.0	5.0
Total (%)	100.0	100.0	100.0

Table 9 Results of measurements in male 8020 achievers and in males with normal occlusion

		Elderly Male (n=10)		Normal Male (n=16)		
		Mean	SD	Mean	SD	*t*-test
Maxillary Arch	Coronal Arch A-width	37.67	1.79	38.64	2.69	n.s.
	Coronal Arch P-width	50.50	3.54	50.23	3.00	n.s.
	Coronal Arch A-length	12.26	1.97	13.58	1.60	n.s.
	Coronal Arch P-length	30.51	2.89	32.81	2.91	n.s.
	Basal Arch A-width	42.77	5.52	44.17	3.90	n.s.
	Basal Arch P-width	65.85	3.20	64.89	4.34	n.s.
	Basal Arch A-length	7.51	2.48	9.61	2.54	*
	Basal Arch P-length	25.71	2.73	27.89	3.54	n.s.
Mandibular Arch	Coronal Arch A-width	30.01	2.28	32.06	3.71	n.s.
	Coronal Arch P-width	44.55	3.91	44.44	4.05	n.s.
	Coronal Arch A-length	8.03	1.44	9.98	2.74	n.s.
	Coronal Arch P-length	26.12	2.30	28.56	2.34	*
	Basal Arch A-width	30.00	4.77	35.39	6.57	*
	Basal Arch P-width	62.41	3.46	60.34	4.59	n.s.
	Basal Arch A-length	2.47	2.01	6.24	1.98	***
	Basal Arch P-length	20.78	2.82	25.79	2.87	***

(Unit: mm)

*p<5%, **p<1%, ***p<0.1% n.s.: non-significant difference

at a 1% level ($p<0.01$), significantly larger Basal Arch A-width and Basal Arch A-length, at a 5% level, and significantly larger Basal Arch P-width, at an 1% level ($p<0.01$), than the females with normal occlusion. In the mandibular arch, the female 8020 achievers showed significantly smaller Coronal Arch A-length and Coronal Arch P-length, at a 1% level ($p<0.01$), and significantly smaller Coronal Arch A-width, Basal Arch A-width, Basal Arch A-length, and Basal Arch P-length, at a 0.1% ($p<0.001$). All measurements with significant intergroup differences were smaller in the female 8020 achievers than in the females with normal occlusion, except for maxillary Basal Arch A-width, maxillary Basal

Table 10 Results of measurements in female 8020 achievers and in females with normal occlusion

		Elderly Female (n=10)		Normal Female (n=16)		
		Mean	SD	Mean	SD	*t*-test
Maxillary Arch	Coronal Arch A-width	36.65	2.95	39.23	2.45	**
	Coronal Arch P-width	48.03	1.66	47.25	2.40	n.s.
	Coronal Arch A-length	12.60	1.25	13.64	1.37	n.s.
	Coronal Arch P-length	30.71	1.52	32.67	1.40	**
	Basal Arch A-width	41.51	6.34	36.99	2.47	*
	Basal Arch P-width	64.41	2.30	60.44	3.44	**
	Basal Arch A-length	8.15	2.14	6.51	1.42	*
	Basal Arch P-length	26.33	2.11	25.60	2.21	n.s.
Mandibular Arch	Coronal Arch A-width	28.72	1.57	31.45	1.44	***
	Coronal Arch P-width	42.29	1.43	40.81	2.71	n.s.
	Coronal Arch A-length	7.90	0.98	9.14	1.03	**
	Coronal Arch P-length	25.82	1.94	28.07	1.43	**
	Basal Arch A-width	23.44	4.60	31.49	1.66	***
	Basal Arch P-width	57.27	3.68	58.49	2.04	n.s.
	Basal Arch A-length	2.44	0.96	5.43	1.25	***
	Basal Arch P-length	20.50	1.67	24.29	1.35	***

(Unit: mm)

*p<5%, **p<1%, ***p<0.1% n.s.: non-significant difference

Arch P-width, and maxillary Basal Arch A-length, which were larger in the female 8020 achievers (Table 10).

Discussion

1. Intraoral status in the 8020 achievers

The average number of remaining teeth in this selected group of twenty 8020 achievers was 28.3 teeth, 65% of which were sound teeth. Most tooth types showed 100% or nearly 100% retention rates. Both the overbite and overjet relationships between the maxillary and mandibular incisors were within the normal range in 75% of the 8020 achievers.

2. Dental arch dimensions

The literature contains several longitudinal studies on model analysis in samples with normal occlusion and other samples[2–4,6,9,10,13,19,21]. This study compared dental arch dimensions between the 8020 achievers and young people in their 20's with normal occlusion. The maxillary Coronal Arch A-width was significantly smaller in the female 8020 achievers than in the females with normal occlusion. This is in agreement with the results of the longitudinal studies by Bishara *et al.*[3], Carter and McNamara[4], Henrikson *et al.*[10], Dager *et al.*[6], Tanoi *et al.*[19], and Tsiopas *et al.*[21]. Harris[9] reported that this dimension decreased with age. Results on maxillary arch width are controversial, with some showing increases and others showing decreases. This may be due to the confounding effect of perioral muscle function.

In the mandibular arch, both the male and female 8020 achievers exhibited significantly smaller A-widths, A-lengths, and P-lengths for both the basal and coronal arches than their normal occlusion counterparts. The result on Coronal Arch A-width are in concordance with those reported by Bishara *et al.*[3], Carter and McNamara[4], Dager *et al.*[6], Tanoi *et al.*[19], and Tsiopas *et al.*[21] in their longitudinal studies. The Coronal Arch A-length and P-length measurements obtained in the present study are similar to the ones reported by Tanoi *et al.*[19] and Tsiopas *et al.*[21]. Equal

numbers of males and females with normal occlusion were enrolled in the studies by Bishara *et al.*[2,3] (15 male, 15 female) and Dager *et al.*[6] (20 male, 20 female), while the sex ratio was unbalanced in the other studies. The results of the present study that were in accord with those reported by Bishara *et al.*[2,3] and Dager *et al.*[6] may thus be regarded as indicating age-related changes.

In the present study, the normal range of overjet and overbite was set at a slightly higher value than the generally accepted normal range of 2–3 mm for adults. Dager *et al.*[6] reported that there was little change in overjet or overbite in a longitudinal study following subjects from the average age of 17 to 58.4 years. Tanoi *et al.*[19] observed increases in overjet from 1.33 to 2.17 mm and in overbite from 1.76 to 2.41 mm over a period of 20 years in subjects with an average age of 22 to 42 years. Further longitudinal studies may clarify the effect of aging on the overjet and overbite values in 8020 achievers.

The molar relationship was Class I in 65% of the 8020 achievers. Harris[9], Dager *et al.*[6], and Tsiopas *et al.*[21] stated that there was little change in molar relationship over time. These results suggest that aging may have little influence on molar relationship.

The 8020 achievers had minimal crowding in the maxillary arch and a small amount of crowding in the mandibular arch. While Carter and McNamara[4] reported no change in the amount of maxillary anterior crowding, studies by Carter and McNamara[4], Dager *et al.*[6], Tanoi *et al.*[19], Tibana *et al.*[20], and Tsiopas *et al.*[21] revealed increases in mandibular anterior crowding.

From these results, narrowing of the mandibular intercanine width and shortening of the mandibular anterior and posterior arch lengths can be regarded as factors contributing to dental crowding.

Conclusion

Three-dimensional dental model analysis in twenty 8020 achievers revealed narrowing of the mandibular intercanine width and shortening of the mandibular anterior and posterior lengths.

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