Sexual dimorphism related to occlusal traits in Australian children

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Background: The aim of the present study was to assess sexual dimorphism related to occlusal variables recorded from dental casts of Australian twins and to compare trends across primary (T1), mixed (T2) and permanent (T3) dentitions in the same individuals.

Methods: The sample comprised 22 males and 25 females selected at random from monozygotic pairs and 19 males and 19 females from dizygotic pairs. Overjet, overbite, midline deviation, midline diastema, primary and permanent molar relationship, and primary and permanent canine relationships were measured in millimetres using a digital calliper.

Results: The mean values for overjet in males in the permanent dentition and for overbite in the mixed and permanent dentitions were significantly greater than those for females. The other occlusal traits showed no sexual dimorphism. Midline diastemata were most prevalent in the primary dentition while coincident midlines were most prevalent at all stages for both genders. In addition, a mesial step deciduous molar relationship was more prevalent on the right side and a flush terminal plane present on the left. Furthermore, a Class II permanent molar relationship was predominant in T1/T2, while a Class I relationship was most prevalent in the permanent dentition. Class II primary and permanent canine relationships were most common at all stages.

Conclusions: Significant sexual dimorphism was found for overjet and overbite at several occlusal developmental stages but sexual dimorphism was not found for the other occlusal traits studied.

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Introduction

During development, the occlusal relationships of the dental arches pass through a series of modifications to adapt to the vertical, transverse and antero-posterior growth of the maxilla and mandible. Changes in the dentitions, from primary to mixed and then to permanent, are essential to achieve normal occlusion.[1,2] Increases in arch length and arch breadth during the mixed dentition phase help to create space to accommodate the erupting permanent dentition in the maxilla and mandible.[3] In the late mixed dentition, the 'leeway space' provides space to accommodate the erupting canines as well as allow mesial migration of the permanent lower first molars into a Class I relationship.[2] In the primary dentition, spacing, which includes upper and lower primate spaces as well as generalised spacing throughout the arch,[1] is a normal and an important finding for uneventful replacement and alignment of the larger anterior permanent teeth.

Sexual dimorphism is evident in males and females in relation to tooth crown size and its magnitude and patterning vary from tooth to tooth, as well as between populations.[4-7] Males present larger dental crown dimensions, on average, than females[8] and this is evident through the primary and permanent dentitions.[9] Changes in arch dimensions during growth also present a degree of sexual dimorphism, as males display an increase of 1.3 mm on average in arch circumference in the maxilla compared with 0.5 mm in females, while arch circumference tends to decrease in the mandible, in males by an average of 3.4 mm and in females by an average of 4.5 mm.[2]

The present study forms part of a larger investigation of occlusal variation and speech development in Australian children. Specifically, it focuses on serial changes in occlusal variables across three developmental stages within individuals and makes comparisons between males and females. The aim of the present study is to describe the nature and extent of normal variation in occlusal features in the primary, mixed, and permanent dentitions of males and females from a sample of Australian children enrolled into ongoing research of dentofacial development of Australian twins and their families in the Adelaide Dental School, The University of Adelaide.[10] It also aims to compare the findings with published data obtained from other populations, as well as to provide updated reference data for occlusal development in Australian children.

Materials and methods

The study sample consisted of males and females selected from monozygotic (MZ) and dizygotic same-sex (DZSS) twin pairs who were enrolled in an ongoing study of dentofacial development of Australian twins and their families in the Adelaide Dental School, The University of Adelaide.

Serial dental casts obtained from the primary (T1), mixed (T2), and permanent (T3) dentitions of individuals were used and only individuals who presented with all three sets of models were included. The sample therefore consisted of 22 MZ males, 19 DZSS males, 25 MZ females, and 19 DZSS females, with one co-twin of each pair randomly selected to avoid bias that would be introduced if data from both twins were assessed, as twins share, on average, all (MZ twins) or half (DZSS twins) of their genes. Zygosity was determined by analysing highly polymorphic DNA markers on 10 chromosomes extracted from cheek cells, with less than 1% probability of dizygosity given concordance.[11] All participants were of European ancestry with no relevant medical or dental history, including no orthodontic treatment or extractions. Ethical approval was obtained from The University of Adelaide Human Research Ethics Committee (H-07-1984A). The focus of this study was on describing occlusal changes over time, using only one member of each twin pair, to enable extrapolations to be made about occlusal variation in the general population. Genetic analyses partitioning observed variation into genetic and environmental components will form the basis of additional papers in the series.

Measurements of overjet (OJ), overbite (OB), midline deviation (middev), midline diastema (middias), molar relationship in the primary (mdr) and permanent (mpr) dentitions on both right and left sides, and canine relationship in the primary (cdr) and permanent (cpr) dentitions on the right and left sides, were recorded in millimetres (mm) to 0.1 mm accuracy using a hand-held digital calliper with sharpened beaks (Mitutoyo, Japan). Measurements were obtained with the upper and lower models positioned in maximum (intercuspal) occlusion and defined by:

Overjet (OJ): the horizontal distance from the upper right central incisor tip to the labial surface of the opposing incisor in the mandible, measured with the calliper level with the occlusal plane. A reverse OJ was recorded as a negative value.[12]

Overbite (OB): the vertical distance from the incisal edge of the upper central incisor and labial surface of the corresponding lower incisor by making a pencil mark on the labial surface of the lower incisor. In the case of an open bite, the gap between incisal edges was measured and given a negative value.[12]

Midline deviation (middev): the difference between the upper and lower midlines, scored as zero if the midlines were coincident (<0.5 mm difference), negative if the lower midline had shifted to the right (>0.5 mm difference), and positive if the lower midline had shifted to the left (>0.5 mm).[13]

Midline diastema (middias): measured in millimetres as the width between the mesial anatomical contact points of the upper central incisors parallel to the occlusal plane. A diastema was recorded as present if the distance was greater than zero.

The molar relationship was measured in the primary dentition (mdr) when the first permanent molars had not erupted or were not in occlusion. The relationship was determined by the distal surfaces of the primary second molars parallel to the occlusal plane and scored as: a distal step, if the distal surface of the lower primary second molar was more distal (>1 mm) than the upper primary second molar; a flush terminal plane, if the distal surface of the upper and lower primary second molars were level; and a mesial step, when the distal surface of the lower primary second molar was more mesial than the upper primary second molar (>1 mm).

The molar relationship in the permanent dentition was determined by the position of the mesio-buccal cusp of the upper molar and the buccal groove of the lower molar, and classified as a Class I if the mesio-buccal cusp tip of the upper molar occluded in the lower molar groove +/- 1 mm, a Class II if the mesio-buccal cusp tip of upper molar occluded more than 1 mm mesial to the lower molar groove, and a Class III if the mesio-buccal cusp tip of upper molar occluded more than 1 mm distal to the lower molar groove.[12]

The canine relationship was recorded as the horizontal deviation of the upper canine cusp tip relative to the lower canine-first premolar or primary first molar in the primary dentition. The distance was recorded as zero if the upper canine tip occluded in the embrasure (Class I), negative if the upper canine tip was mesial to the embrasure (Class II), and positive if the upper canine tip was distal to the embrasure (Class III).[13]

Statistical analysis

Descriptive statistics including mean values and standard deviations (SD) were calculated for the metric variables according to zygosity, genders, dentition, and left and right sides. Mean values and variances were compared using linear regression analysis, paired *t*-tests and mixed effect modelling, and *p*-values < 0.05 were considered significant. Frequencies were used to describe the categorical data and then presented as percentages. Wilcoxon Rank Sum Tests were used to assess sexual dimorphism in categorical data. Double determinations were performed by two operators (DCR and RL). Reproducibility was assessed for 22 subjects by using paired *t*-tests[14] and repeatability was assessed by using Dahlberg's statistic.[15] A *p*-value of less than 0.05 was considered significant.

Results

Only three of the 22 occlusal variables showed significant differences between the first and second determinations, with mean differences being small and unlikely to bias results. Dahlberg statistics ranged from 0.1 mm for midline diastema to 0.6 mm for the permanent left canine relationship, confirming that random errors were small in magnitude.

Sample sizes varied between the study variables because some participants did not have full primary or permanent dentitions when impressions were obtained. Teeth that were not fully erupted were excluded and so this also contributed to smaller sample sizes for some variables. Analyses of histograms showed that all metric variables were approximately normally distributed and could therefore be represented by mean values and standard deviations. Values for OJ and OB increased from the primary to the permanent dentition in both males and females for both zygosities. Because no significant differences were found between zygosities, data from MZ males and DZSS males, as well as data from MZ females and DZ females, were pooled to increase sample sizes and statistical power (Table I). Overall, males presented larger values than females for OJ and OB for all stages of development, except for OJ in the primary dentition, where males and females displayed the same value (Table I). There was a significant increase in OJ and OB values from the primary to the mixed dentition and this was evident for males and females,

Table I. Mean values and standard deviations for overjet (OJ) and overbite (OB) in males and females (in mm) from pooled MZ and DZSS twin data in the primary (T1), mixed (T2), and permanent (T3) dentitions.

		Primary (T1)		Mixed (T2)		Permanent (T3)	
		N	mean (+/- SD)	N	mean (+/- SD)	N	mean (+/- SD)
Males							
	OJ	39	2.5 (0.90)^{*T}	41	3.5 (0.90)	40	3.5 (1.09)**
	OB	39	2.1 (1.41)^{*T}	41	4.0 (1.35)**	40	4.0 (1.85)**
Females							
	OJ	43	2.5 (1.20)^{*T}	44	3.1 (0.20)	43	3.0 (1.14)
	OB	41	1.7 (1.49)^{*T}	44	2.9 (1.59)	41	3.3 (1.27)

N = sample size; mean = mean values; SD = standard deviation. (*Significant difference between primary (T1) and mixed (T2) dentitions. ^{T}Significant difference between primary (T1) and permanent (T3) dentitions at $p < 0.05$. Significant differences between corresponding values in males and females at $p < 0.05$).

while no significant increases were found in OJ or OB from the mixed to the permanent dentition for both genders. Significant differences between males and females were found in OJ in the permanent dentition ($p = 0.0436$), and in OB in the mixed ($p = 0.0002$) and permanent ($p = 0.0425$) dentitions.

Percentage frequencies of midline diastema, midline deviation, primary and permanent molar relationship, and primary and permanent canine relationship for males and females are presented in Table II. Midline diastemata were more prevalent in the primary dentition for both males (51%) and females (57%) and less prevalent in the permanent dentition, as males presented with diastemata in 17% and females displayed diastemata in 25% of the sample.

Percentages of midline deviation showed that coincident upper and lower midlines presented the highest prevalence in males (T1: 55%; T2: 59%; T3: 45%) and females (T1: 49%; T2: 57%; T3: 49%) in all stages of development. No differences in midline deviation pattern were found between right and left sides or between the genders (Table II).

Percentage frequencies for the molar relationship were obtained from the primary and the permanent dentitions and for both the right and left sides. Males and females presented a higher frequency of mesial step primary molar relationship on the right side (48% and 58% respectively), while a higher frequency of a flush terminal plane was found on the left side for males (42%) and females (42%) at stage T1. The permanent molar relationship also varied across all stages studied, with males and females displaying a higher frequency of Class II molar relationship on the right side (73% and 70% respectively) and left side (82% and 56% respectively) in stage T1, while a higher frequency of Class I molar relationship was found in stage T3 for both males and females on the right (49% and 48% respectively) and left (55% and 58% respectively) sides.

The primary canine relationship was recorded for males and females and for both the right and left sides at stage T1 and T2, and showed a higher frequency of Class II canine relationship for males and females on the right (71% and 49%, respectively) and left (68% and 56%, respectively) sides at stage T1. Stage T2 showed a higher prevalence of Class II primary canine relationship for males and females on the right (50% and 47%, respectively) side, and for left side in males (47%), while females showed higher frequency of Class I primary canine relationship on the left side (46%). Percentage frequencies of permanent canine relationship were only collected at stage T3 and a Class II relationship was most common in males on the right (66%) and left (62%) sides, while females displayed a more Class II permanent canine relationship on the right (63%) and a Class I on the left (53%) side.

Most epidemiological studies of OJ and OB use a categorical approach to present data, and so direct comparisons with the present study are not possible. Nevertheless, there have been several previous studies involving Australians,[16] North American whites,[17] and Finnish[18] populations in which values have been reported in millimetres, and so some comparisons are provided in Table III. Overall, similar values of OJ and OB have been reported at all three stages of development (T1, T2 and T3) for all populations studied. The larger mean values for OJ in males in the present population compared with North American whites and Finns may have been due to the different measurement techniques employed.

There is a shortage of published data on OJ and OB in the primary dentition (stage T1) in other populations. A previous study[16] based on Australian children reported similar OJ and OB values in the primary dentition, but this is not surprising as the data in the current study were derived using the same twin cohort as that used by Hughes et al. (2001).

Discussion

Sexual dimorphism

Sexual dimorphism in the human dentition seems to be influenced by both of the sex chromosomes[19,20] and sex hormones[21,22] but its magnitude and pattern varies according to the feature studied. In the present study, sexual dimorphism was assessed for all occlusal variables, but only OJ and OB displayed a small but statistically significant difference between males and females at certain stages of development. Males displayed significantly larger values than females for OJ in the permanent dentition (T3), while OB showed significant differences between males and females in the mixed (T2) and permanent (T3) dentitions.

Overall, mean values of OJ and OB in males at all three stages were greater than those for females but these differences were not statistically significant (Table I). In males, there was a significant increase in OJ from T1 to T2 and T1 to T3, but no significant

Table II. Frequencies of midline diastema, midline deviation, primary molar relationship, permanent molar relationship, primary canine relationship, permanent canine relationship of males and females from monozygotic (MZ) and dizygotic (DZSS) twins in the primary (T1), mixed (T2), and permanent (T3) dentitions.

			Primary (T1)		Mixed (T2)		Permanent (T3)	
			N	%	N	%	N	%
middias								
	Males							
		No	35	49	40	52	42	83
		Yes	35	51	40	48	42	17
	Females							
		No	42	43	41	41	44	75
		Yes	42	57	41	59	44	25
middev								
	Males							
		Right	33	24	41	19	42	19
		Equal	33	55	41	59	42	45
		Left	33	21	41	22	42	36
	Females							
		Right	35	17	44	15	45	24
		Equal	35	49	44	57	45	49
		Left	35	34	44	28	45	27
mdr								
	Males							
	Right	Mesial	31	48				
		Flush terminal	31	16				
		Distal	31	35				
	Left	Mesial	31	32				
		Flush terminal	31	42				
		Distal	31	26				
	Females							
	Right	Mesial	34	58				
		Flush terminal	34	21				
		Distal	34	21				
	Left	Mesial	33	30				
		Flush terminal	33	42				
		Distal	33	27				
mpr								
	Males							
	Right	Class I	11	27	42	24	41	49
		Class II	11	73	42	69	41	34
		Class III	11	-	42	7	41	17
	Left	Class I	11	18	42	48	42	55
		Class II	11	82	42	52	42	26
		Class III	11	-	42	-	42	19
	Females							
	Right	Class I	10	30	44	20	44	48
		Class II	10	70	44	50	44	32
		Class III	10	-	44	5	44	20
	Left	Class I	9	44	44	52	45	58
		Class II	9	56	44	46	45	24
		Class III	9	-	44	2	45	18
cdr								
	Males							
	Right	Class I	42	26	34	44		
		Class II	42	71	34	50		
		Class III	42	2	34	6		
	Left	Class I	41	27	34	41		
		Class II	41	68	34	44		
		Class III	41	5	34	15		
	Females							
	Right	Class I	43	47	34	41		
		Class II	43	49	34	47		
		Class III	43	5	34	12		
	Left	Class I	43	17	28	46		
		Class II	43	56	28	43		
		Class III	43	5	28	11		
cpr								
	Males							
	Right	Class I					38	34
		Class II					38	66
		Class III					38	0
	Left	Class I					37	35
		Class II					37	62
		Class III					37	3
	Females							
	Right	Class I					41	34
		Class II					41	63
		Class III					41	2
	Left	Class I					36	53
		Class II					36	44
		Class III					36	3

N = mean values; % = percentage values; middias = midline diastema; middev = midline deviation; mdr = primary molar relationship; mpr = permanent molar relationship; cdr = primary canine relationship; cpr = permanent canine relationship.

Table III. Overjet (OJ) and overbite (OB) values in the primary, mixed and permanent dentitions of males and females in different populations measured in mm.

		Our data			Australians[a]			North American whites[b]			Finns[c]		
		N	Mean (mm)	SD	N	Mean (mm)	SD	N	Mean (mm)	SE	N	Mean (mm)	SD
Males													
T1													
	OJ	40	2.6	0.90	92	2.5	1.10						
	OB	40	2.0	1.50	92	2.0	1.00						
T2													
	OJ	41	3.6	0.70				1153	3.4	0.05	12	3.3	1.00
	OB	41	4.0	1.40				1163	3.2	0.11	12	2.9	1.20
T3													
	OJ	42	3.5	1.10				1153	3.3	0.13	15	3.3	0.80
	OB	42	4.0	1.80				1163	3.1	0.14	15	3.2	1.00
Females													
T1													
	OJ	43	2.5	1.20	97	2.3	1.50						
	OB	41	1.6	1.60	97	1.5	1.70						
T2													
	OJ	44	3.1	1.40				1153	3.3	0.10	15	2.9	1.20
	OB	44	2.9	1.60				1163	2.9	0.11	15	2.6	1.50
T3													
	OJ	45	3.0	1.10				1153	2.8	0.09	18	3.3	0.90
	OB	45	3.3	1.30				1163	2.8	0.12	18	3.4	0.90

N = sample size; mean (mm) = mean values in millimetres; SD = standard deviation; SE = standard error; OJ = overjet; OB = overbite; T1 = primary dentition; T2: mixed dentition; T3: permanent dentition; [a](Hughes et al., 2001), [b](Brunelle et al., 1996), [c](Heikinheimo et al., 2012).

difference between T2 and T3. The same pattern was also found for OB in males. In females, there was a significant increase in OJ and OB from T1 to T2 and T1 to T3, but no significant difference was found between T2 and T3. This agrees with previous longitudinal studies that reported increases in OJ[23] and OB[24] from the primary to permanent dentitions in most of the subjects studied and in both males and females. No significant gender differences were found in the present sample for the other studied occlusal traits (midline diastema, midline deviation, deciduous and permanent molar relationship, deciduous and permanent canine relationship) and this is consistent with previous studies that found no sexual dimorphism in occlusal traits for any of the stages studied.[25]

Patterns of development in occlusal traits

The patterns of development in OJ and OB varied from T1 to T3, with a statistically significant increase in OJ values from stages T1 to T2 for males and females, while no significant difference in OJ was found between stages T2 and T3. This contrasts with data published in a longitudinal study that found a modest but statistically significant increase in OJ and OB from the mixed to the permanent dentitions in both genders.[26]

Maxillary midline diastema is more common in the primary and mixed dentitions than in the permanent dentition and tends to close when the maxillary permanent canines erupt.[1] In the present sample, the frequency of midline diastema (middias) varied across the three stages for males and females, as the permanent dentition displayed the lowest prevalence of midline diastema (17% in males and 25% in females) compared with the other stages studied, while the primary dentition displayed the highest frequency of midline diastemata for males (51%) and females (57%). The current results are in agreement with previous studies that have reported a decrease in the size of the midline diastema during the adolescent period.[17,25,27]

The literature reports that asymmetries greater than 2 mm between the upper and lower midlines are considered unaesthetic by most people[28] and an assessment should include both the dental and facial midlines, as well as any inconsistencies in the occlusion such as premature contacts that could lead to functional mandibular displacements.[29]

The present results show that most of the upper and lower dental midlines were coincident in all stages studied for males (T1: 55%; T2: 59%; T3: 45%) and females (T1: 49%; T2: 57%; T3: 49%), when dental casts were manipulated by hand into maximum intercuspation. This contrasts with the findings of a cross-sectional study that reported a high prevalence of non-coincident midlines in a sample of Italian adolescents.[25] Given that the present data were obtained from dental casts and recording was restricted to percentage frequencies of upper and lower midline deviations, caution is needed when comparing the data as no clinical information, such as mandibular displacements due to premature contact or facial midline data, was available.

During growth, it is important to appreciate the nature of the changes in the sagittal plane between the primary and the permanent dentitions, as the initial occlusion of the permanent first molars depends on the terminal plane relationship of the primary second molars.[30-32] The literature reports that, if an individual presents a distal terminal plane, it is anticipated that the permanent first molars will erupt in a Class II relationship, while a more mesial terminal plane relationship of the primary second molars will likely develop into a Class I molar relationship in the permanent dentition.[30,31,33] In the present sample, the primary second molar relationships were recorded only at stage T1 and they showed the highest percentage incidence of mesial step for males and females on the right (48% and 58%, respectively) and the highest percentage incidence of flush terminal plane on the left side (42% and 42%, respectively) (Table II). Some epidemiological data on the prevalence of primary molar relationship have shown that a flush terminal plane is the most common in pre-school children from different populations,[34-36] while other authors have reported a high incidence of mesial step for both males and females.[33] Fernandes and colleagues, in an epidemiological study using an Indian pre-school children sample, concluded that the prevalence of primary molar relationship varied according to individual age and gender.[37]

Data on the permanent molar relationships were collected at stage T1 and showed a high frequency of Class II molar relationship for both sides and both genders. However, these data should be analysed with caution due to the small sample sizes available (Table II). Males presented a higher incidence of Class II molar relationship at stage T2 on both sides (right: 69%; left: 52%), while stage T3 showed more Class I molar relationships on both sides (right: 49%; left: 55%). A similar pattern of prevalence was found for females with a higher incidence of Class II molar relationship on the right side (50%) and a Class I molar relationship on the left side (52%), while stage T3 displayed more Class I molar relationships on both sides (right: 48%; left: 58%) (Table II). This agrees with epidemiological studies related to orthodontic treatment need in different populations, in which normal or Class I molar relationships have been found to be the most common in the permanent dentition.[17]

When individuals were considered at each stage of development (T1, T2 and T3) and data were compared on an individual basis, similar trends were found for both males and females to those reflected in the summary statistics reported in the Results section. For example, for all males who presented with a Class II permanent molar relationship on the left side in the primary dentition (N = 6), the majority continued with a Class II molar relationship in the mixed dentition (N = 4) and permanent dentition (N = 4). This is in agreement with longitudinal studies that have shown that Class II molar relationships early during development do not self-correct with growth and rarely become Class I molar relationships over time.[31]

To enable direct comparisons with published data, findings for permanent molar relationships on the right and left sides in Australian children were combined. These comparisons confirmed that occlusal relationships in Australian children are similar to those reported by Bishara and colleagues for American children.[31] It was reported that, from a mesial step (41%) occlusion in the primary dentition, 76.2% of children became Class I in the permanent dentition, with 22.8% becoming either Class II or Class III on at least one side.

Considering that permanent canines only emerge into the oral cavity at around 10 to 12 years of age, results for the primary canine relationship have only been reported at stage T1 and T2, while at stage T3 prevalence has been reported for the permanent canine relationship. The present results showed a high frequency of Class II primary canine relationship at stage T1 in males and females, for both the right (males: 57%; females: 49%) and left sides (males: 68%; females: 56%). This agrees with studies that have reported a high frequency of Class I primary canine relationship in stage T1 and T2.[16,36,38] Data on permanent canine relationship showed that most children displayed a Class II permanent canine relationship at stage T3 on both sides in males (right: 66%; left: 62%) and females on the right (63%) side, while a high incidence of Class I permanent canine relationship was seen on the left side (53%). This is in agreement with a longitudinal study that reported a high prevalence of Class II permanent canine relationship in the permanent dentition.[23]

Limitations of the present study

Because data were collected from dental models, measurements of midline deviations were obtained using the upper dental midline as a reference, as no other reliable soft tissue frontal references were available. Furthermore, data were collected by articulating the upper and lower dental casts by hand to achieve maximum intercuspal occlusion as no wax bites were available to assist in occluding the models.

Conclusion

Sexual dimorphism was evident in OJ and OB, with significant differences between males and females found for OJ in the permanent (T3) dentition, and for OB in the mixed (T2) and permanent (T3) dentitions. Overall, the pattern of development across the three stages studied showed significant increases in OJ values from primary (T1) to mixed (T2) dentitions, and from primary (T1) to permanent (T3) dentitions. The same pattern was evident for OB in both males and females. Furthermore, no significant differences were found between males and females for the other occlusal traits studied. This study provides new reference data for occlusal variables in Australian children for use by clinicians.

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Conflict of interest

The authors have no conflict of interest to declare.

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