Evaluation of mandibular morphology in different facial types

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Abstract

The purpose of this study was to evaluate mandibular morphology in different facial types using various parameters. This study was conducted on lateral cephalograms of a total of 110 subjects, which included 55 males and 55 females between the age of 18–25 years having a mean of 22.3 years for males and 21.5 years for females. The sample was divided into normodivergent, hypodivergent, and hyperdivergent subgroups based on Jarabak's ratio. Symphysis height, depth, ratio (height/depth) and angle, antegonial notch depth, ramal height and width, mandibular depth, upper, lower, and total gonial angle, and mandibular arc angle were analyzed statistically and graphically. It was found that the mandible with the vertical growth pattern was associated with a symphysis with large height, small depth, large ratio, small angle, decreased ramus height and width, smaller mandibular depth, increased gonial angle, and decreased mandibular arc angle in contrast to mandible with a horizontal growth pattern. Sexual dichotomy was found with mean symphysis height and depth in the female sample being smaller than in the male sample, but symphysis ratio was larger in the female sample; males having greater ramus height and width, mandibular depth than females. The mandible seemed to have retained its infantile characteristics with all its processes underdeveloped in hyperdivergent group.

Keywords: Hyperdivergent, hypodivergent, mandibular morphology

Introduction

Facial growth and development are of deep concern to the clinician, because the amount and direction of growth will significantly alter the need for orthodontic biomechanics. Orthodontists have long been interested in the multitude of the difference in the diagnosis, treatment, and responses between hyperdivergent and hypodivergent facial types. A reliable method of growth prediction would be an invaluable asset to orthodontists. With the introduction of radiographic cephalometry, the interest in the variability of facial patterns was advanced. Now facial types could be studied with emphasis on their association with malocclusions and skeletal relationships. Schudy[1] investigated the interaction of anteroposterior and vertical facial dysplasias and emphasized the importance of the vertical facial dimension in orthodontic treatment.

It has been well documented that morphology of natural reference structures was accurate and effective as a basis for cephalometric research (Bjork[2] and Buschang[3]). Although the ability to predict growth of the entire face would be most desirable, in orthodontics, knowledge of mandibular growth would be highly beneficial in diagnosis and treatment planning and is critical in the development of balanced dentofacial structures. Previous investigators assessed a variety of methods to predict mandibular growth, and various parameters have been used with varying success. Although many cephalometric measurements have been used, it has been shown that it is still very difficult to accurately predict the direction of mandibular growth using a particular parameter. According to Bjork,[2] not all the morphologic features would be found in a particular individual, but the greater the number present the more reliable the prediction would be. Although related, multiple morphologic factors were most useful in explaining the clinical vertical evaluation of facial patterns (Fields HW *et al*[4]). The purpose of this study was to

- Evaluate mandibular morphology in different facial types using various parameters.
- To implicate the achieved results into diagnosis and treatment planning of patients requiring orthodontic treatment.

Materials and Methods

This study was conducted on lateral cephalograms of a total of 110 subjects, which included 55 males and 55 females between the age of 18–25 years having a mean of 22.3 years for males and 21.5 years for females. The sample was divided into normodivergent, hypodivergent, and hyperdivergent subgroups based on Jarabak's ratio. The subjects comprising normodivergent, hypodivergent, and hyperdivergent groups were selected as per the following guidelines:

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Selection criteria - Normodivergent (control) group

- Angle's Class I molar relationship
- Overjet and overbite within normal limits
- No decayed/missing/filled teeth
- Pleasant profile
- No history of orthodontic treatment
- No facial asymmetry
- No history of trauma or surgery in the dentofacial region

Hypodivergent and hyperdivergent study group

- None of the individuals had undergone any orthodontic treatment previously
- No facial asymmetry
- All the permanent teeth present with Class I or II molar relationship

Sample division into vertical and horizontal facial types using Jarabak's ratio [Table 1].

Methods

After orienting the patient in NHP, lateral cephalograms were obtained with teeth in centric occlusion using a Cephalostat. Kodak X-ray films (8 × 10 inches) were exposed at 70 KVP; 30 mA from a fixed distance of 60 inches with standard procedures used in the Department of Orthodontics, D.A.V © Dental College, Yamunanagar.

The radiographs were traced on acetate tracing paper with a 4H sharp pencil on a view box using transilluminated light in a dark room. The linear and angular measurements were measured to the nearest of 0.5 mm and 0.5 degree, respectively, with the help of a scale and protractor.

The various parameters used for study were as follows:

Cephalometric landmarks [Figure 1]

- N: Nasion—the anterior most point of the frontonasal suture in the median plane.
- Or: Orbitale—lowermost point of the orbit in the radiograph.
- Po: Porion—the most superiorly positioned point of the external auditory meatus (anatomical porion).
- Ba: Basion—lowest point on the anterior margin on the foramen magnum in the median plane.
- Dc: Condyle—the point in the center of the condyle neck along the Ba-N plane.
- Point B—the most posterior point in the outer contour of the mandibular alveolar process in the median plane.
- PM (Suprapogonion)—the point at which the shape of the symphysis mentalis changes from convex to concave, also known as protuberance menti.
- Pog: Pogonion—most anterior point of the bony chin, in the median plane.
- Gn: Gnathion—point constructed by intersecting a line drawn perpendicularly to the line connecting Pog and Me with the bony outline.

Table 1: Sample segregation

Group	Sex	Jarabak's ratio (%)	Total sample
Normodivergent	M	62–65	25
	F	62–65	25
Hyperdivergent	M	<62	15
	F	<62	15
Hyperdivergent	M	<65	15
	F	<65	15

- Me: Menton—lowermost point on the outline of symphysis as seen in norma lateralis.
- Go: Gonion—point of intersection of lines tangent to lower and posterior ramal borders of mandible projected on mandible (Brodie 1941).
- Ar: Articulare—the point of intersection of the images of the posterior margin of ascending ramus and the outer margin of cranial base.
- Xi point—the location of the Xi point is keyed geometrically to the Frankfort horizontal (FH) and the pterygoid root vertical planes (PtV). This procedure follows:

1. Locate FH and draw PtV plane perpendicular to the FH plane.
2. Construct four planes tangent to points R-1, R-2, R-3, and R-4 on the borders of the ramus.
   R-1: The deepest point on the anterior border of the ramus, located halfway between the superior and the inferior curves.
   R-2: Located on the posterior border of the ramus, opposite R-1.
   R-3: The deepest point of the sigmoid notch, halfway between the anterior and the posterior curves.
   R-4: Opposite R-3 on the inferior border of the mandible.
3. The constructed planes form a rectangle enclosing the ramus.
4. Xi point is located in the center of the rectangle at the intersection of the diagonals.

Cephalometric planes

1. FHP: Frankfort horizontal plane—extends from Porion to Orbitale.
2. PTV: Pterygoid vertical—the vertical line drawn through the distal radiographic outline of the Pterygomaxillary fissure and perpendicular to the Frankfort horizontal plane.
3. Mandibular plane (Tweed's)—tangent to the lower border of the mandible.
4. Ba-N: Basion-nasion plane—extends from Basion to Nasion.
5. Occlusal plane—plane passing posteriorly through mesiobuccal cusp of first permanent molar and anteriorly bissecting the overbite.

Cephalometric linear measurements [Figure 2]

1. Anterior facial height: distance between N and Me.

2. Posterior facial height: distance between S and Go.
3. Ramus height: distance between Ar and Go.
4. Ramus width: distance between anterior and posterior border of ramus at the height of the occlusal plane.
5. Mandibular depth: distance between Ar and Pog.
6. Symphysis height: calculated as follows:
   A line tangent to point B was used as the long axis of the symphysis, and a grid was formed with the lines of the grid parallel and perpendicular to the constructed tangent line. The superior limit of the symphysis was taken at point B with the inferior, anterior, and posterior limits taken at the most inferior, anterior, and posterior borders of the symphysis outline, respectively (Aki *et al*, 1994).
7. Symphysis depth: distance from anterior to posterior limit on the grid.
8. Antegonial notch depth: distance along a perpendicular line from the deepest part of notch concavity to a tangent through the two points of greatest convexity on the inferior border of the mandible, either side of the notch (Singer *et al*, 1994).

Cephalometric angular measurements [Figure 3]

1. Frankfort mandibular plane angle: angle formed between FHP and mandibular plane (Tweeds, 1954).
2. Symphysis angle: posteriosuperior angle formed by the line through Me and point B and the mandibular plane (Aki *et al*, 1994).
3. Gonial angle: angle formed by the points Ar, Go and Me at Go.
4. Upper Gonial angle: angle formed by the points Ar, Go, N at Go.
5. Lower Gonial angle: angle formed by the points N, Go, Me at Go.
6. Mandibular arc angle: posterosuperior angle formed by the points Dc, Xi, Pm at Xi.

Statistical analysis

Error of measurement

Fifteen cephalograms were selected at random, retraced, and measurements were obtained after 2 weeks to evaluate the reliability and reproducibility of landmarks and measurements. Minimal error indicated that the reliability rate of all measurements was fair.

Mean and standard deviation of each variable were calculated for all the groups. Analysis of variance was also performed to determine if there was a difference between sexes and between groups for each of these measurements.

Discussion

In this study, the sample consisting of 110 subjects was divided according to Jarabak's ratio as used earlier by Wylie[5] and Bishara.[6] Additionally, FMA angle was also included.

Subjects falling within 18–25 years were selected because of the fact that most of the growth would have been completed by that time. Also a constant skeletal pattern gets established, as Brodie[7] said that the facial patterns once established did not change much. In addition, Bishara[6] in his longitudinal

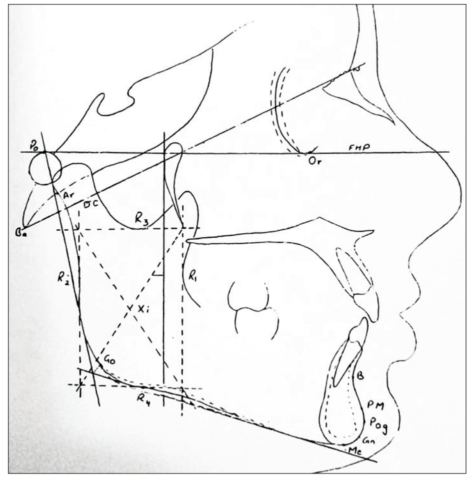

Figure 1: Cephalometric landmarks

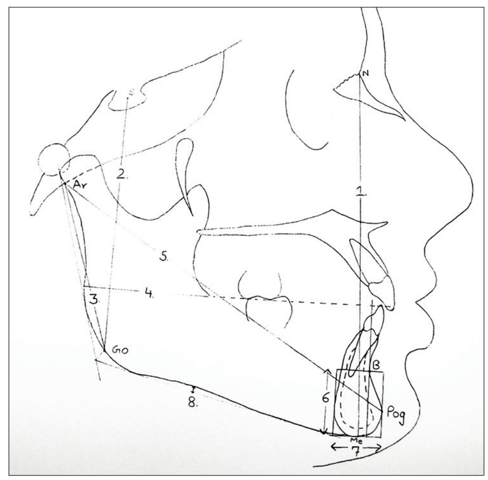

Figure 2: Cephalometric linear measurements

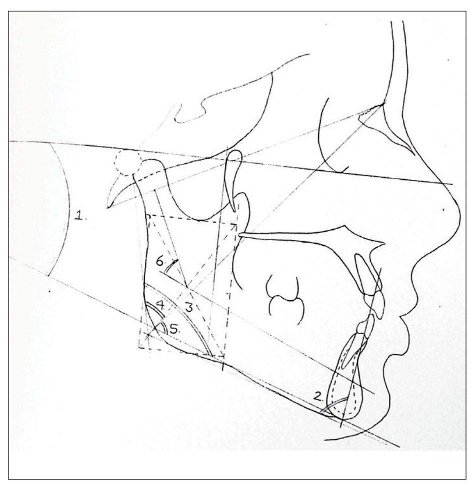

Figure 3: Cephalometric angular measurements

study concluded that the differences among facial types were more pronounced at adulthood. Studies have shown that the growth changes of the facial tissues, although not completed, occurred predominantly before the age of 18 years (Brodie[8], Nanda[8]).

It has been assumed by many investigators that extreme values of mandibular plane angle were prognostic criteria for predicting the direction of facial growth. However, Baumrind *et al*,[9] and Skieller and Bjork[10] suggested that a high mandibular plane angle was not a good predictor of facial growth and that individuals with high mandibular plane angle could have both backward and forward mandibular growth patterns, Nanda.[11]

A well-established sexual dimorphism in the facial dimension had been found to exist by various researchers in the various facial types (Jarabak and Siriwat,[12] Bishara and Jakobsen,[6] Nanda,[13] Schudy[14]). So there was a need to segregate the sample according to sex to maintain the homogeneity of the sample.

In our study, the depth of the antegonial notch was found to be highest in hyperdivergent group with no sexual dichotomy [Table 2]. The results were statistically significant except in male hypodivergent versus normal and hyperdivergent group. Similar findings have been reported by Singer *et al*,[15] Bjork and Skieller,[16] Becker,[15] and Bjork[2] in their implant studies, Lambrechts *et al*[17] reported significant difference in the various cephalometric measurements indicating the nature of mandibular growth in two groups with extreme notch depth. Kolodziej *et al*,[18] however, found statistically significant negative relationship between mandibular antegonial notch depth and subsequent horizontal jaw growth.

Symphysis in hypodivergent facial type was found to be associated with short height, large depth, small ratio (height/depth), and larger angle. In contrast, a symphysis with a larger height, smaller depth, larger ratio, and a smaller angle exists in hyperdivergent group [Table 2]. These results are consistent with the findings of Aki *et al.*,[19] Ricketts,[20] Viazis[21] who found a thick symphysis to be associated with an anterior growth direction. Sassouni V.[22] and Bjork[2] have found a tendency toward backward mandibular rotation to be associated with the pronounced apposition below the symphysis with more overall concavity of the lower mandibular border. Also, sexual dichotomy found in the study was consistent with findings of Aki *et al*.,[19] who found that mean symphyseal height and depth in females being smaller than in the male sample. The symphysis ratio was larger in the female sample indicating that mean symphysis depth was less in female than in the male subjects.

Gonial angle was found to be significantly increased in hyperdivergent group when compared with control and hypodivergent group and also in control group when compared with hypodivergent group [Table 3]. Numerous investigators, Jensen,[11] Schendel,[23] Opdebeeck,[24] Sassouni *et al.*,[25] DeCoster,[11] Swinehat EW,[11] Hapak,[11] Subtelny,[26] Nahoum,[27,28] Trouten,[29] Cangialosi,[30] Fields *et al.*,[4] Siriwat,[12] have also indicated that an obtuse gonial angle was associated with a skeletal open bite while a relatively small angle was associated with a deep bite. The lack in the development of posterior facial height and increased anterior lower facial height results in a downward and backward rotation of mandible and an increase in mandibular plane angle and gonial angle as suggested by Sassouni.[31]

Ramus width measured at the level of occlusal plane was found to be increased in hypodivergent when compared with normodivergent and hyperdivergent [Table 4]. No significant sexual dichotomy was found except in hyperdivergent group. Ramus height was also found to be significantly increased in hypodivergent and normodivergent groups when compared with hyperdivergent group [Table 4]. Significant sexual dichotomy was found. The findings were in agreement with the observation of Swinehart,[13] Sassouni,[32] Muller,[33] Schudy,[1] and Sassouni,[25] all of whom reported a considerable deficiency in dimension in hyperdivergent group.

Mandibular depth was found to be significantly increased in hypodivergent and normodivergent when compared with hyperdivergent group and also increased in hypodivergent group when compared with normodivergent group [Table 4]. The results were in agreement with the studies of Hellman[29] who found shorter corpus in open bite. Schudy[1] postulated that increased vertical proportions were usually accompanied by lesser anteroposterior dimensions and vice versa. Sassouni[22] also found shorter depth of mandible in hyperdivergent facial type in combination with Class I or Class II malocclusion. Pollard *et al.*[34] found that the overall mandibular length (Co-Gn) increase highly correlated with ramal height and body length changes. He also found mandibular length measurements from condylion and articulare highly correlative, suggesting that articulare may be substituted for condylion. However, statistically significant sexual dimorphism was found in this study, as was observed by Bishara SE[35] and Formby *et al*.[8] They found mandibular depth to be increased in males when compared with females. According to Formby,[8] on the whole, females showed smaller growth changes than males and males having more total changes in skeletal depth at pogonion. He also found skeletal depth at pogonion correlated positively with the posterior facial height, which meant that as the posterior dimension increased in adult males, the mandible tended to rotate anteriorly. The changes in skeletal depth of pogonion were also larger for males in Behrent's[8] study. Aki T *et al*.[19] said that the deposition of bone at the pogonion was highly variable and appears to be sex-linked.

Table 2: Mean linear measurements (comparison between groups)

Variables	Normal (Control)			Hypo			Hyper		
	M	F	NKT	M	F	NKT	M	F	NKT
Symphysis height	24.0	21.6	4.7xx	22.0	20.4	1.6	24.8	22.8	2.9x
Symphysis depth	15.0	13.64	3x	15.67	14.3	2.25x	14.0	13.1	1.8
Antegonial notch depth	1.09	1.11	0.1x	1.13	1.19	0.13	1.67	2.03	1.28
Mandibular depth	116.7	110.4	4.48xx	117.6	112	3.04x	110.9	105.7	2.8x
Ramus height	53.0	48.0	7.4xx	55.5	52	2.8x	46.3	41.7	3.4x
Ramus width	32.0	31.4	0.7x	34.1	32.6	1.4	31.7	29.2	3.0x

xSignificant (*P*<0.05,<0.01).; xxHighly significant (*P*<0.001).

Table 3: Angular measurements (comparison between groups)

Variables	Normo vs Hyper NKT		Normo vs hypo NKT		Hyper vs hypo NKT	
	M	F	M	F	M	F
FMA	4.17xx	3.4x	4.96xx	4.98xx	7.4xx	5.66xx
Gonial angle	3.5x	3.15x	2.26x	2.74x	5.39xx	5.7xx
Upper gonial angle	2.1	2.74x	0.3xx	1.29	1.57xx	0.98
Lower gonial angle	1.49	2.47x	4.58xx	4.24xx	4.5xx	4.68xx
Mandibular arc angle	1.08	3.18x	4.22xx	3.38x	4.38xx	6.04xx
Symphysis angle	1.48	1.48	2.06x	2.1x	2.95x	2.67x

xSignificant (*P*<0.05, <0.01).; xxHighly significant (*P*<0.001).

Table 4: Linear measurements (comparison between groups)

Variables	Normo vs Hyper NKT		Normo vs hypo NKT		Hyper vs hypo NKT	
	M	F	M	F	M	F
Symphysis height	1.32	2.36x	2.75x	1.74	3.57x	2.86x
Symphysis depth	1.97	1.09	1.17	1.24	2.94x	2.04x
Antegonial notch depth	2.36x	2.92xx	0.18	0.25x	1.79	2.36x
Mandibular depth	3.22x	2.84x	0.5	1.29	3.92xx	3.46x
Ramus height	5.4xx	5.4xx	2x	3.68xx	7.3xx	7.7xx
Ramus width	0.24x	3.07x	2.3x	1.36	2.52x	3.68xx

xSignificant (*P*<0.05,<0.01).; xxHighly significant (*P*<0.001)

Table 5: Mean angular measurements (comparison between groups)

Variables	Normal (Control)			Hypo			Hyper		
	M	F	NKT	M	F	NKT	M	F	NKT
FMA	23.0	24.8	1.66	16.8	18.6	1.23	28.3	30.7	0.8
Gonial angle	125.7	127	0.9	121.8	122	0.19	131	133.6	1.03
Upper gonial angle	52.1	51.5	0.57	52.5	53.2	0.43	55.5	55.1	0.2
Lower gonial angle	73.6	75.6	1.90	68.0	69.0	0.53	75.7	79.2	2.0
Mandibular arc angle	35.9	36.3	0.3	42.4	41.4	0.7	34.3	31.07	1.6
Symphysis angle	81.0	81.0	0.03	84.5	85.3	0.38	78.7	77.6	0.45

Mandibular arc angle measurement used to describe direction of condylar growth (Mc Dowell[36]) was found to be significantly increased in hyperdivergent group when compared with hypodivergent and normodivergent groups [Table 3]. No significant sexual dichotomy was found [Table 5]. As used by Ricketts[37] in his analysis, mandibular arc (corpus-condyle axis) was found to be 27.8 degrees in mesofacial (standard), while it was greater than normal in brachyfacial type and reverse pattern was seen in dolichofacial types (Platau).[37] Owen AH[38] used mandibular arc angle for diagnosis and treatment planning in vertical plane to indicate the tendency of the mandible for clockwise or counter clockwise growth with values <21 degrees indicating clockwise and >31 degrees indicating counter-clockwise growth trend. Bench *et al.*[39] also in his study said that mandibular arc of 25 degree and above was a strong indicator for strong functional (muscular) response.

Clinical perspective

In the past, much attention has been given to the diagnosis and treatment of anteroposterior malrelationships of the dental arches. However, the cases that have proved most difficult to treat and which have the least favorable prognosis are frequently those in which there is a vertical discrepancy. This fact was amply demonstrated by the fact that relapse in the vertical dimension of a treated case is the first sign to be noted.

Prediction of growth pattern by the morphology of mandible of an individual had clinical implications in treatment planning for the patient. Extraction decision, type of anchorage preparation, mechanics, and retention period are influenced by the growth pattern which an individual possesses.

The size and shape of the mandibular symphysis was an important consideration in evaluation of orthodontic patients. With a larger symphysis, more protrusion of the incisors was esthetically acceptable and therefore greater chances of a nonextraction approach to treatment. Conversely, patients with greater symphysis height and a small chin would be candidates for an extraction treatment plan to compensate for arch length discrepancies.

The morphologic differences between patients with long and short facial type results in a significant difference in the mechanical advantage of the jaw muscles. As the gonial angle increased in patients with long facial types, the mechanical advantage of the adductor muscles decreases and vice versa. With the increase in ramus height, there was an increase in mechanical advantage of the masseter muscle. Hence, the patients with short facial type overall have a significantly large mechanical advantage than compared with the long face group. Some surgical procedures used to correct facial disharmonies may have a significant effect on the mechanical advantage of the jaw muscles. Mandibular advancement, for example, will decrease mechanical advantage of adductor muscles.

This had a bearing on the orthodontic tooth movement, and account must be taken of this in planning treatment. Orthodontists have been concerned with bite force because vertical forces are often produced in the process of treating malocclusions, as in use of Class II elastics or tip back bends. Sometimes it is desirable that bite forces negate these orthodontic forces. Additionally, the influence of bite force on the vertical stability of any treatment result is important. The new position of the dentition should be compatible with the dynamics of the muscular and occlusal forces in all planes. There is a serious risk of extreme migration after extractions in vertical facial types, and secure anchorage is required. The conservation and preservation of anchorage is a critical factor in the space management in individuals with long faces when compared with short faces.

Also higher extrusive forces are required to overcome the increased mechanical advantage of the musculature in short facial types. However, such forces are controlled along with a closer check on the sagittal changes to overcome the mesial migratory forces on the dentition in vertical facial types because of the weaker musculature.

The short ramus height associated with long face and skeletal open bite does not permit the mandibular ramus surgery to be carried out alone to correct the problem. This rotation lengthens the ramus and stretches the muscles of the pterygoid sling, causing the relapse to occur, and hence should be combined with maxillary intrusion to avoid any ramus lengthening.

In addition, the significant findings of the various parameters as supported by multiple studies in different facial types divided according to Jarabak's ratio support Jarabak's ratio to be a good indicator of the growth pattern of an individual.

Conclusions

- The symphysis with the vertical growth pattern had a large height, small depth, large ratio, and small angle. In contrast, a symphysis with a horizontal growth pattern had a small height, large depth, small ratio, and large angle. Sexual dichotomy was found with mean symphysis height and depth in the female sample being smaller than in the male sample but symphysis ratio was larger in the female sample.
- The ramus height was found to be significantly smaller in hyperdivergent group than hypodivergent group. Sexual dimorphism was significantly evident with males having greater ramus height than females. The ramus width was also found to be smaller in hyperdivergent group and males possessed greater values than females.
- Mandibular depth showed smaller values in hyperdivergent group and definite sexual dichotomy with greater values in males were found.
- Antegonial notch depth revealed greater values in hyperdivergent group and no sexual dimorphism was found.
- Gonial angle, FMA, and mandibular arc angle were found to be significantly increased in hyperdivergent group with no sexual dimorphism.
- The mandible seemed to have retained its infantile characteristics with all its processes underdeveloped in hyperdivergent group.

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