Comparative study of linear and angular measures of the cranial base in skeletal Class I and III malocclusion

Estudo comparativo de medições lineares e angulares da base do crânio em maloclusão esquelética Classe I e III

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Abstract

Purpose: To evaluate the effect of flexion and linear measures of the cranial base on the anteroposterior position of the jaws in skeletal Class III malocclusion compared with skeletal Class I.

Methods: One hundred-twenty lateral radiographs were divided in two groups: Group 1 - 60 radiographs of individuals with a Class I skeletal pattern; and Group 2 - 60 radiographs of individuals with a skeletal Class III pattern. The radiographs were of adult Caucasian individuals with no previous orthodontic treatment. Data were analyzed by using ANOVA.

Results: There were significant differences in the cranial base angle (NSBa) and anterior cranial base length (S-N) between the two groups. Group 2 had the lowest values for NSBa and S-N. The analysis of cranial base complementary angles (NSGn and BaSGn) revealed a significant statistical difference in NSGn: Group 2 had lower NSGn values, which indicates a more anterior position of the gnathion. Variations of the cranial base angle and the Y axis were inversely correlated with variations of SNA and SNB angles, and the differences were statistically significant for the two groups.

Conclusion: This study supports previous findings that the cranial base flexion contributes to skeletal configuration in Class III skeletal patterns. Therefore, the cranial base should be evaluated for growth predictions and Class III diagnosis. The effect of the cranial base on the positioning of the jaws should be further assessed.

Key words: Cranial base; cephalometry; Class III malocclusion

Resumo

Objetivo: Avaliar o efeito da flexão a das medidas lineares da base do crânio na posição anteroposterior da maxila e da mandíbula na maloclusão de Classe III esquelética através da comparação com a Classe I esquelética.

Métodos: A amostra selecionada foi composta de 120 radiografias cefalométricas, em norma lateral, divididas em dois grupos: Grupo 1: 60 radiografias de indivíduos com padrão de Classe I esquelética; e Grupo 2: 60 radiografias de indivíduos com padrão de Classe III esquelética. As radiografias selecionadas foram de indivíduos adultos, Caucasianos e sem tratamento ortodôntico prévio. Os dados foram analisados por ANOVA.

Resultados: Houve diferença significativa no ângulo da base do crânio (NSBa) e no comprimento da base anterior do crânio (S-N) entre os dois grupos. O Grupo 2 obteve valores menores para NSBa e S-N. A análise dos ângulos complementares da base do crânio (NSGn and BaSGn) revelou uma diferença estatisticamente significativa no NSGn: O Grupo 2 obteve menores valores de NSG o que indica uma posição mais anterior do gnátio. Variações no ângulo da base do crânio e no eixo Y foram inversamente correlacionadas com variações nos ângulos SNA e SNB, e as diferenças foram estatisticamente significativas para os dois grupos.

Conclusão: Este estudo concorda com estudos anteriores de que a flexão da base do crânio contribui para a configuração esquelética no padrão de Classe III esquelética. Logo, a base do crânio deve ser avaliada nas previsões de crescimento e no diagnóstico da Classe III. O estudo do efeito da base do crânio no posicionamento dos maxilares deve ser mais aprofundado.

Palavras-chave: Base do crânio; cefalometria; maloclusão de Classe III

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Introduction

Facial structures, as well as their functions and correlations, have been extensively studied to expand the knowledge of craniofacial growth and development and to optimize growth predictions and proper indications of orthodontic and surgical treatments.

The cranial base sets the boundaries of the cranial and facial skeleton. The nasomaxillary complex is associated with the anterior cranial base, whereas the mandible is associated with its posterior portion. Therefore, the shape of the cranial base is an important factor in establishing the position of the maxilla (1). The growth and development of this region is accelerated and occurs at an early age in comparison with other regions in the craniofacial complex. Therefore, the cranial base is less exposed to environmental factors and, as its development is mostly determined genetically, its development does not need other stimuli and cannot be affected by orthodontic or orthopedic forces. The face is dependent on the shape and size of the cranial base (2). According to Enlow (3), the cranial floor is the base upon which the face is built. The length and height of specific parts of the cranial floor are expressed in equivalent facial dimensions. The growth of each facial region involves two basic factors: the amount of growth of a certain part, and the direction of growth of this part (3).

The cranial base determines the positioning of the maxilla and the mandible. The sagittal movement of the maxilla during growth, measured from a point parallel to the S-N line, is associated with the changes that occur during growth in the cranial base angle (NSBa). The rotation of the lateral parts of the cranial base may be transmitted through the zygomatic bone in the maxilla and may have a direct mechanical effect on the direction of the downward movement of the upper facial structures (4).

In the relation with the mandible, however, any change in the form of the cranial base will affect the displacement of the glenoid fossa, and this movement will directly affect the degree of mandibular protrusion. Total mandibular protrusion depends on its growth in length in the condyle and its direction, as well as the displacement of the mandibular body due to the sutural growth of the cranial base. The cranial base reaches 90% of its final length by age 4 to 5 (6). Because of that, clearly defined signs of the malocclusion that the individual will have in the future may be seen in childhood, and malocclusion may be detected by means of a careful evaluation of the craniofacial skeleton on a lateral radiograph.

This study evaluated the effect of the cranial base angle and length on the development of skeletal Class III malocclusion by comparing their effect with those seen on skeletal Class I. The purpose of this study was to show that anatomic characteristics of the cranial base may provide an accurate prediction of growth in young patients.

Methodology

Sample

Lateral radiographs were obtained from the clinical records of male and female Caucasian adults without previous orthodontic treatment at the Orthodontics and Facial Orthopedics Clinic of the School of Dentistry of Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS). The radiographs were traced to produce cephalograms, and the SNA, SNB and ANB angles were measured. Inclusion criteria were: no tooth missing (except third molars); ANB > 0 degrees and < 4.5 degrees (Tweed, 1966) (7) for Class I; ANB > -1 degree for Class III. To define the skeletal Class III sample better and exclude borderline or dubious cases, only individuals with ANB < -1 degree were selected. The final sample comprised 60 skeletal Class I (Group 1) and 60 skeletal Class III (Group 2) radiographs.

Measures

Angular and linear dimensions were measured using a Cephalometric Protractor (3M-UNITEK), at 0.5 degrees and 0.5 mm intervals. Group 1 (Class I) measures were compared with those obtained for Group 2 (Class III). To evaluate the morphological behavior of the cranial base in Class III, Group 2 was divided into three subclasses:

a) Class III caused by maxillary deficiency: SNA < 82 degrees
b) Class III caused by mandibular excess: SNB > 80 degrees
c) Class III caused by combinations of both maxillary deficiency and mandibular excess: SNA < 82 degrees and SNB > 80 degrees.

Cranial base characteristics were evaluated in the three Class III subclasses using statistical analysis to calculate means and standard deviations of angles (NSBa and NSGn) and linear (S-N and Ba-S) measures.

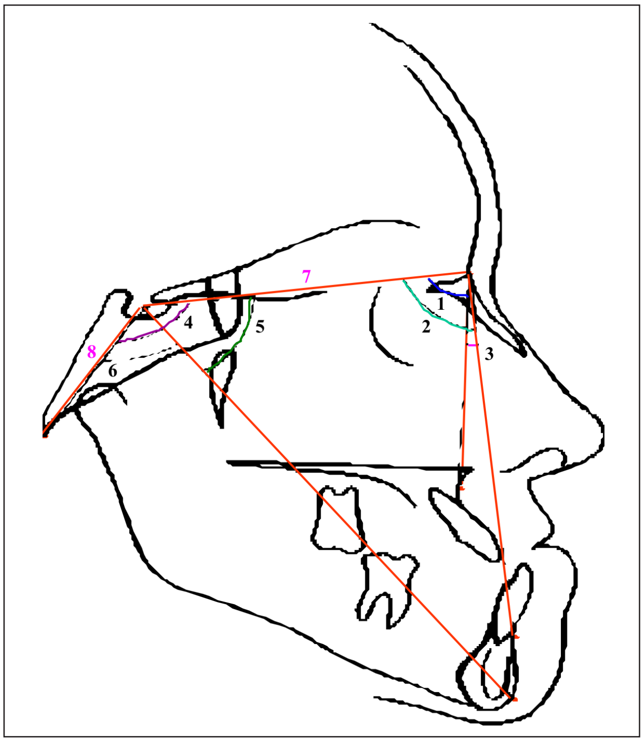

Fig. 1. Tracings of angles and linear measures used in this study: 1. SNA angle; 2. SNB angle; 3. ANB angle; 4. NSBa angle; 5. NSGn angle; 6. BaSGn angle; 7. S-N line; 8. Ba-S line.

Statistical Analysis

Tracings and measurements were made in 20% of the sample by the same operator and repeated two weeks later Houston (8). The results of correlation analysis showed that measures at time point 1 and time point 2 were strongly correlated. The *t* test for paired samples was used at a 5% level of confidence, and results did not show any significant differences between measures at time point 1 and time point 2 for any sample. ANOVA and the Pearson Correlation coefficient were used for the statistical analyses of data obtained for angle and linear measures on radiograph tracings.

Results

The values obtained in each series of measurements and their statistical analyses are shown in Tables 1-4. The Pearson Correlation Coefficients for Class III and Class I are shown in Table 5. Table 6 shows descriptive statistics of the NSBa and NSGn cranial base angles and the S-N and Ba-S linear measures in the three Class III subclasses.

Table 1. Descriptive statistics for NSBa cranial base angle (degrees).

Sex	Class				Sex Total	
	Class I		Class III			
	Mean	SD	Mean	SD	Mean	SD
Men	128.52	5.37	126.14	4.91	127.47^{a}	5.26
Women	131.38	5.21	129.88	4.55	130.56^{b}	4.88
Total for Class	130.04^{B}	5.43	128.51^{A}	4.99	129.28	5.25

Mean values followed by upper- or lowercase letters have statistical significant differences according to ANOVA at a 5% level of significance.

Table 2. Descriptive statistics for S-N (mm) and Ba-S (mm) linear measures.

Sex	Class								Sex Total			
	Class I				Class III							
	Mean		SD		Mean		SD		Mean		SD	
	S-N	Ba-S	S-N	Ba-S	S-N	Ba-S	S-N	Ba-S	S-N	Ba-S	S-N	Ba-S
Men	76.91	49.93	3.58	3.68	73.70	50.23	4.76	3.69	75.50^{b}	50.06^{b}	4.40	3.65
Women	72.16	46.8	3.09	2.53	69.93	45.42	3.45	4.01	70.95^{a}	46.05^{a}	3.45	3.46
Total Class	74.38^{B}	48.26	4.07	3.47	71.32^{A}	47.18	4.35	4.51	72.85	47.72	4.47	4.05

Mean values followed by upper- or lowercase letters have statistical significant differences according to ANOVA at a 5% level of significance.

Table 3. Descriptive statistics for NSGn angle (degrees).

Sex	Class				Sex Total	
	Class I		Class III			
	Mean	SD	Mean	SD	Mean	S.D
Men	67.07	4.65	65.00	4.84	66.16	4.80
Women	68.16	3.60	64.51	5.35	66.18	4.95
Total Class	67.65^{B}	4.12	64.69^{A}	5.13	66.17	4.87

Mean values followed by upper- or lowercase letters have statistical significant differences according to ANOVA at a 5% level of significance.

Table 4. Descriptive statistics for BaSGn angle (degrees).

Sex	Class				Sex Total	
	Class I		Class III			
	Mean	SD	Mean	SD	Mean	SD
Men	61.45	6.13	61.36	5.81	61.41^{a}	5.93
Women	63.22	5.80	65.39	6.25	64.40^{b}	6.10
Total Class	62.39	5.97	63.92	6.35	63.15	6.19

Mean values followed by upper- or lowercase letters have statistical significant differences according to ANOVA at a 5% level of significance.

Table 5. Significant results of correlation analysis – Class III and Class I.

CLASS	Correlation	Pearson correlation coefficient	*P*
CLASS III	SNA X SNB	0.773	0.01*
CLASS I	SNB X SNA	0.901	0.01*
CLASS III	SNB X ANB	-0.394	0.01*
CLASS I	SNA X ANB	0.353	0.01*
CLASS III	NSBa X SNA	-0.339	0.01*
CLASS I	NSBa X SNA	-0.515	0.01*
CLASS III	NSBa X SNB	-0.325	0.05*
CLASS I	NSBa X SNB	-0.516	0.01*
CLASS III	NSGn X SNA	-0.413	0.01*
CLASS I	NSGn X SNA	-0.645	0.01*
CLASS III	NSGn X SNB	-0.542	0.01*
CLASS I	NSGn X SNB	-0.693	0.01*
CLASS III	BaSGn X NSBa	0.611	0.01*
CLASS I	BaSGn X NSBa	0.742	0.01*
CLASS III	BaSGn X NSGn	-0.644	0.01*
CLASS I	BaSGn X NSGn	-0.471	0.01*
CLASS I	N-S X NSGn	-0.351	0.01*
CLASS I	Ba-S X SNB	0.260	0.05*
CLASS III	N-S X NSBa	-0.271	0.05*
CLASS III	Ba-S X S-N	0.456	0.01*
CLASS I	Ba-S X S-N	0.358	0.01*

Table 6. Descriptive statistics of NSBa and NSGn cranial base angles and S-N and Ba-S linear measures according to Class III subclasses.

		N	Cephalometric measures		*P*
			Mean*	SD	
NSBa	Maxillary deficiency	16	132.41^{a}	4.92	<0.001
	Mandibular excess	38	127.45^{b}	4.03	
	Both	6	124.83^{b}	5.19	
NSGn	Maxillary deficiency	16	67.47^{a}	6.75	0.026
	Mandibular excess	38	63.42^{b}	4.20	
	Both	6	65.33^{ab}	2.42	
S-N	Maxillary deficiency	16	71.59^{a}	3.34	0.298
	Mandibular excess	38	70.82^{a}	4.38	
	Both	6	73.75^{a}	6.19	
Ba-S	Maxillary deficiency	16	47.81^{a}	4.27	0.787
	Mandibular excess	38	47.03^{a}	4.77	
	Both	6	46.50^{a}	3.94	

* Means followed by different letters are significantly different according to ANOVA followed by the Tukey multiple comparison test.

Discussion

At birth, the cranial base angle (or saddle angle) measures 142 degrees and decreases to 130 degrees at the age of 5 years. From age 5 to 15, the NSBa angle remains stable (9). According to Kerr and Hirst (9), this stability suggests that the NSBa angle at 5 years may be, in 73% of all individuals, an accurate predictive factor of the skeletal path that will be followed up to age 15 years. In the literature, mean NSBa values range from 130 degrees (10) to 133.47 degrees (11).

In the orthodontic and anthropological literature, several studies suggest that there is an association between the shape and length of the cranial base and skeletal malocclusion (12-15). Some authors studied the behavior of the cranial base in Class III malocclusion and its effect on the sagittal positioning of the maxilla and mandible and found low mean values for the cranial base angle (11,12,14-21).Our results confirm those findings: mean cranial base angle (NSBa) in individuals with Class III malocclusion was 128.51 degrees, a significantly lower value (Table 1).

The results of this study, as well as previous findings (11,16-18,20,21), suggest that mandibular prognathism is inversely correlated with the degree of flexion of the cranial base: greater flexion of the cranial base leads to a more anterior positioning of the temporomandibular joint and, consequently, to mandibular protrusion.

For Class I malocclusion, the mean value of the NSBa angle found in this study was 130.04 degrees (Table 1), and was very similar to the values found in other studies (10,13,16,19,22). The mean value of the NSBa angle was significantly higher in women than in men, both in Class I (131.8 degrees) and Class III (129.88 degrees; Table 1).

This study also evaluated the linear dimensions of the cranial base in Class III malocclusion. Results are described according to length, in mm, from anterior (S-N) to posterior (Ba-S). There were significant differences in length of anterior cranial base when class ($P<0.001$) and sex ($P<0.001$) were analyzed. Class III had significant smaller mean values (71.32 mm) than Class I (74.38 mm) (Table 2). Riolo (1974) (23) reported that the normal length of the anterior cranial base, the S-N line, measures about 78 mm.

A short anterior cranial base has been described as an etiological factor to maxillary retrusion, which results in Class III malocclusion (18), but some authors found minor significant differences (17,24) or even no differences (11) in cranial base length between Class I and Class III. According to some studies, the total cranial base length (Ba-S) is shorter in Class III than in Class I (14,18).

Data in the literature are controversial, especially about the role of the anterior cranial base (sella-nasion) in Class III malocclusion, because there is great variation of the nasion during growth, which contributes to different findings in samples of growing patients (24,25).

Our analysis according to sex showed that mean values were higher for men (75.50 mm; Table 2), and this difference was statistically significant ($P<0.001$). According to Ursi et al. (25), a possible explanation for this dimorphism is that the anterior cranial base boundary (nasion) is a portion of the frontal bone, which increases its width by deposition on its surface during lifetime and by an increase in the frontal sinus pneumatization, particularly in teenagers; therefore, this area of the frontal bone has a greater mean width in men. In our study, the lower mean values of S-N length were found in women with Class III malocclusion (69.93 mm). There were no statistically significant differences in posterior cranial base (Ba-S) measures between Class I and Class III. A smaller mean value was found in women (46.05 mm) than in men (50.06 mm; Table 2). This result is in agreement with those reported by URSI et al (26), who found a significant difference between sexes in Ba-S at the age of 18, with values of 44.8 mm for women and 48 mm for men. The authors concluded that sexual dimorphism becomes evident in most skeletal measures at the age of 14 years.

A significant statistical difference was found in the NSGn angle between Class I and Class III ($P<0.001$): the mean value in the Class I group was 67.65 degrees and in the Class III group, 64.69 degrees (Table 3). This angle is classified as a complementary angle of the cranial base (16) and the Y axis for growth (26), and defines the vector for anterior and lower growth of the mandible. As in Class III, its value was lower, which suggests that there was a variation in Gn position in relation to the NSBa angle vertex in both groups. In this sample, most individuals in the Class III group had the symphysis menti positioned at a higher and more anterior point than in the Class I group. Therefore, CCW mandibular rotation was predominant, which may be explained by the fact that most individuals with Class III malocclusion had mandibular excess (SNB>80 degrees), and the correlation between NSGn and SNB angles (Table 5) was inversely significant ($P<0.01$).

The NSGn angle did not differ significantly between sexes (Table 3), and their values were very similar. The BaSGn angle was not statistically different between individuals in the Class I (62.39 degrees) and Class III (63.92 degrees) groups (Table 4).

In Class I, the significant and inverse correlations of NSBa angle with SNA and SNB angles (Tables 6) showed that the values of SNA and SNB angles decrease as the values of the NSBa angle increases, and the SNA and SNB angle increases as the NSBa angle decreases, findings that are in agreement with those reported by Bjork (10). Dhopaktar et al. (27) found a similar correlation index for SNB and NSBa angle in Class I (r=-0.54; $P<0.01$).

The correlation of SNA and SNB with the complementary cranial base angle, NSGn, indicates that the mandibular growth direction (Y axis of growth) was significant and inverse (Table 5). This shows that SNA and SNB decrease when NSGn increases and characterizes CW mandibular rotation. If the NSGn values decrease, the SNA and SNB values increase in relation to the SNB and NSGn correlation, which characterizes CCW mandibular rotation. The NSGn angle had a significant and inverse correlation with the BaSGn angle (Table 5), which indicates that these angles have an opposite behavior because of Gn variation. The correlation between the two linear measures of the anterior (S-N) and posterior (Ba-S) cranial base was direct and significant (Table 5).

In individuals with Classes I and III skeletal patterns, the correlations between NSBa cranial base angle, SNA and SNB are significant and inverse. Therefore, when NSBa increases, the SNA and SNB angles decrease, and the opposite is also true (Table 5), which is in agreement with the findings reported by Bjork(10). Our results of the SNA and SNB correlation also confirm results reported by Bjork (10), who found the same correlation (P=-0.33) between sagittal displacement of maxilla (SNA) and cranial base angle changes (NSBa) that occurs during growth. Dhopaktar et al. (27) found significant and inverse correlations between the SNA and NSBa (r= -0.47; $P<0.01$) and SNB and NSBa (r=-0.42; $P<0.01$) angles in individuals with Class III malocclusion.

In the Class III group, the NSGn angle had a significant and inverse correlation with the SNA and SNB angles (Table 5), similar to the one found in the Class I group (Table 5). As the NSGn angle decreases, SNA and SNB angles increase, which, in the case of the SNB angle in Class III due to mandibular protrusion, describes a CW mandibular rotation with the B point and, therefore, with Gn to an anterior and upward position. These findings are in agreement with the evidence provided by Walker and Kowalski (28), who argued that correlation coefficients measure the intensity of geometric associations between these two dimensions, and, therefore, might predict the effects that changes in one angle may have on another angle. According to Enlow (3), all malocclusions are characterized by different combinations of regional dimensional disequilibria, and, therefore, dimensional variation is one of the causes of malocclusion because of low or moderate associations between two measures reflect disequilibria and skeletal dysplasia.

In the Class III group, there was a prevalence of mandibular excess (63%), followed by maxillary deficiency (26.7%) and combinations of both (10%) (Table 6). Individuals with mandibular excess (SNB>82 degrees) and those with a combination of mandibular excess and maxillary deficiency (SNB>82 degrees and SNA<80 degrees) in the Class III group (Table 6) had a cranial base angle (NSBa) significantly smaller than those with maxillary deficiency (SNA<80 degrees). Therefore, this study demonstrated that cranial base flexion in Class III malocclusion has a greater effect on mandibular prognathism than on maxillary deficiency. This is also seen in the behavior of the NSGn angle (Y axis of growth), which is significantly smaller in individuals with Class III malocclusion due to mandibular excess, and confirms the more anterior position of the mandible, represented by the gnathion, and, therefore, a more horizontal path of growth.

The linear measures of the anterior (S-N) and posterior (Ba-S) cranial base did not differ significantly between the morphological subclasses of Class III (mandibular excess, maxillary deficiency, or both) (Table 6). Therefore, the anterior and posterior cranial base seemed to have no separate influence on maxillary retrognathism or mandibular prognathism. Our results do not warrant any conclusion as to whether individuals with Class III malocclusion caused by maxillary deficiency or mandibular excess will have shorter anterior or posterior cranial bases.

The prediction of a skeletal Class III malocclusion using morphologic analyses is an important step in orthodontic diagnosis and treatment planning. According to Schulhoff et al. (29), who evaluated normal growth prediction in Class III, the cranial base has 82% accuracy in growth prediction. The progression from mandibular retrognathism in newborns to significant mandibular prognathism in adults with Class III malocclusion follows a series of transitional stages, and questions may be raised about the correct skeletal growth path. Clinicians should be able to predict future growth, a crucial step in making decisions about treatment planning.

According to Silva et al. (2), if genetic factors that lead to Class III malocclusion are identified at an early stage, some intrinsic or extrinsic contributing factors may be prevented or intercepted. In orthodontic diagnosis and prognosis, the morphological characteristics of the cranial base should be taken into consideration because they are greatly affected genetically, and because the cranial base has an earlier growth and development than other regions in the craniofacial complex.

The sample studied here included adults with Class III malocclusion and no treatment, and our findings support the suggestion that the cranial base flexion is a contributing factor to skeletal Class III patterns. Patients with skeletal Class III malocclusion have a more inclined cranial base angle than patients with Class I occlusion. In addition to the smaller NSBA angle values found in the mandibular excess subclass of the Class III group, the correlation between NSGn and SNB angles was inverse and significant, which suggests that mandibular protrusion (SNB) increases as NSGn decreases. This characterizes CCW mandibular rotation and confirms the great contribution of cranial base flexion (NSBa angle) to mandibular prognathism.

Important growth predictive factors should be observed in this area of the skull. These types of malocclusion have a progressive path, mainly due to mandibular growth. Future studies should further investigate the effect of the cranial base on jaw positioning.

Conclusions

Our results showed that:

1. The cranial base angle (NSBa) was smaller in individuals with Class III skeletal patterns.
2. The cranial base (S-N) was shorter in skeletal Class III cases and in women. The posterior cranial base was shorter in women.
3. The individuals in the Class III group had a smaller NSGn than those in the Class I group.
4. The BaSGn angle was greater in women.
5. There was dimorphism between linear and angle measures of the cranial base: women had greater NSBa and BaSGn angles only, and men had greater S-N and Ba-S values only.
6. When only the skeletal Class III cases were analyzed, the mean morphological characteristic was mandibular protrusion in the subclasses of maxillary deficiency and combinations of both. The NSBa and NSGn angles had smaller means in individuals with mandibular excess than in those with maxillary deficiency or combinations of both.

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