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Bolton Anterior Tooth Size Discrepancies Among Different Malocclusion Groups

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ABSTRACT

Orthodontic treatment comprises different phases with unique characteristics and challenges. The orthodontic “finishing” phase is recognized for the multitude of details necessary to achieve an excellent result. In some cases, the finishing phase is very difficult, requiring the production of complicated biomechanical forces to reach a satisfactory orthodontic solution. A high percentage of these finishing-phase difficulties arise because of tooth size imbalances that could have been detected and considered during initial diagnosis and treatment planning. The present study aimed to investigate the correlation between anterior tooth size discrepancies and Angle's Class I, II, and III malocclusions, as well as their prevalence in the Brazilian population from Belo Horizonte. We assessed the mesiodistal width of six anterior teeth in 300 patients, who were selected randomly. These patients were allocated to three groups according to their malocclusion. A chi-square test was performed to statistically compare the prevalence of anterior tooth size discrepancies among the three malocclusion groups and two genders. Analysis of variance was used to compare the mean Bolton anterior tooth size ratios as a function of Angle classification and gender. Statistical differences were determined at the 95% confidence level ($P < .05$). The important conclusions of our study are as follows: (1) Individuals with Angle Class I and Class III malocclusions show significantly greater prevalence of tooth size discrepancies than do individuals with Class II malocclusions; and (2) Mean anterior tooth size discrepancy for Angle Class III subjects was significantly greater than for Class I and Class II subjects.

KEY WORDS: Tooth size discrepancy, Bolton analysis, Bolton ratio, Tooth size analysis, Brazil.

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INTRODUCTION Return to TOC

Orthodontic treatment comprises different phases, and each segment presents unique characteristics and challenges. The orthodontic “ finishing” phase is recognized for the multitude of details necessary to achieve an excellent result. In some cases, the finishing phase is very difficult, requiring the production of complicated biomechanical forces to reach a satisfactory orthodontic solution. A high percentage of these finishing-phase difficulties arise because of tooth size imbalances that could have been detected and considered during initial diagnosis and treatment planning. An excellent orthodontic treatment result with optimal occlusion and ideal intercuspation, overjet, and overbite is often jeopardized by tooth size discrepancies or problematical tooth anatomy. Dental literature is replete with studies comparing tooth size discrepancy and malocclusion in different ethnic groups. However, there is a lack of gender and Angle classification specificity in

these studies, and additional data are necessary to understand this association.

The present study was designed to investigate the relationship between anterior tooth size discrepancies and Angle Class I, II, and III malocclusions in a Brazilian population from Belo Horizonte, Minas Gerais.

The objectives of this investigation were to describe the following:

- Prevalence of anterior tooth size discrepancies in the three Angle malocclusion groups as a function of gender.
- Differences of Bolton's anterior tooth size proportions in Brazilian Class I, II, and III malocclusion groups.

LITERATURE REVIEW Return to TOC

The clinician should be familiar with discrepancies in tooth size at the initial diagnosis and treatment planning stages if excellence in orthodontic finishing is to be achieved. Tooth size discrepancies are considered an important variable especially in the anterior segment. Lavelle[1] stated that although tooth size and proportion have an important role in malocclusion, the study of tooth dimensions has received scant attention by orthodontists.

Genetic influences have been considered important in the determination of tooth dimensions, and the first reports were related to clinical observations within families. Studies on twins, however, helped in understanding the genetic contribution of tooth size in that a greater tooth size correlation was found in monozygotic twins.[2,3] Other investigators de-emphasized the genetic contribution and described the determination of tooth size as multifactorial, with the environment playing an important role.[4] Teratogenic and nutritional factors have been associated with the mechanism of tooth formation.[4] Space limitations and nutrition have been described as important in the development of a healthy tooth germ and have been related to alterations in number, shape, and form of permanent teeth.[4] Although it is widely accepted that both genetic and environmental variables affect tooth development, it is virtually impossible to identify and describe the role each of these variables play in the determination of tooth size.[5]

As in many other human attributes, teeth vary in size between males and females. Gender differences have been reported in the literature and may have clinical relevance. According to Seipel, cited by Lavelle,[6] there are fewer gender differences in the primary dentition than in the permanent dentition. Male teeth are generally recognized to be larger than female teeth.[7–12] In both the primary and permanent dentitions, the upper canines and upper central incisors show the greatest gender differences,[12] whereas the upper lateral incisor and lower central incisor are the most homogenous.[10]

There is lack of agreement regarding gender differences in relation to the tooth size proportion between upper and lower anteriors. Although Lavelle[1] described a difference, Richardson and Malhotra[13] reported no differences in upper and lower anterior tooth size proportions, indicating that there is a constant 77% ratio for both genders. More recently, other studies have reported significant differences in tooth size between males and females but no evidence of a significant difference in upper to lower anterior tooth size proportions.[14,15]

Tooth size differences exist among various ethnic groups, and it is reported that individuals of Black ethnic backgrounds have larger teeth than Caucasians.[1,13,15–18] Studies including Hispanic populations reported significant differences in relation to Caucasians but tooth size similarities to African-Americans.[15,18] The Brazilian population, like the Hispanic population, is composed of a mixture of African and European descendents.

The first concerns expressed in dental literature related to tooth size date back to the 1920s. In different publications, Gilpatric,[19] Young, cited by Bolton,[20] and Stanton[21] stated that there should be a proportion between upper and lower teeth. Gilpatric[19] and later Stanton[21] studied 2000 individuals and found that the upper teeth should be 8- to 12-mm larger than the lower dentition and that a value greater than 8- to 12-mm would result in an excessive overbite.

Several studies were published describing the importance of a correct tooth size proportion between the upper and lower arches. After observing 200 cases, Neff [22] developed a proportion for the width dimension of the teeth called the *anterior coefficient.* He found that an optimal overbite was represented when maxillary mesiodistal sum divided by the mandibular mesiodistal sum resulted in a ratio of 1.20 to 1.22. Lundström[23] studied the relationship between the mandibular and the maxillary anterior sum and named it the *anterior index.* For an ideal overbite, the optimal ratio was found to be from 73% to 85%, with a mean of 79%. Bolton[20,24] evaluated 55 cases with “excellent” occlusion. After considering tooth sizes from canine to canine in the maxillary and mandibular arches, Bolton established an ideal anterior ratio with a mean value of 77.2% and standard deviation (SD) of 1.65%. The author concluded that it would be very difficult to obtain an excellent occlusion in the finishing phase of treatment without a correct mesiodistal tooth size ratio. Bolton's[20,24] articles had a profound impact because most tooth size studies since his publication have used the Bolton tooth size discrepancy analysis to diagnose tooth size discrepancies.

In more recent articles, other variables such as incisor inclinations,[25,26] upper-incisor thickness,[27,28] and arch form[27,29] have been described as important to consider in achieving optimal occlusion relationships. Efforts have been made to adapt the Bolton analysis to these variations. Several authors[27–29] proposed new methods to study tooth size discrepancies. However, these proposals need to be tested in clinical studies and, for now, the Bolton analysis prevails as an efficacious clinical tool for appraising various relationships of upper to lower dentitions.

Orthodontists should be concerned with tooth size discrepancies because of the high incidence in orthodontic patient populations. Bolton[20,24] reported tooth size discrepancies greater than ±1 SD in 29% of the patients studied in his private practice, and Richardson and Malhotra[13] reported similar discrepancies in 33.7% of their patients. Crosby and Alexander[30] stated that a tooth size discrepancy had to be greater than ±2 SD, eg, two to three mm of deviation, to influence the course of orthodontic treatment. In studies involving 109 individuals, 22.9% showed anterior ratios that significantly deviated from the Bolton analysis mean (greater than ±2 SD). Freeman et al[31] found that 30% of 157 subjects studied had an anterior tooth size discrepancy ratio greater than ±2 SD from the Bolton mean. In a more recent study, Santoro et al[18] reinforced the findings of Crosby and Alexander[30] observing that 28% of 54 Dominican Americans presented a discrepancy greater than ±2 SD.

Recently, a correlation among tooth size discrepancies and malocclusion groups has been reported. Lavelle[1] studied 160 subjects for anterior tooth sizes and showed a tendency for Angle Class III individuals to present smaller upper teeth compared with subjects classified as Class II or I. Moreover, Lavelle[1] stated that teeth in the lower arch are larger in Class III than in Classes II and I, with the inference that a Bolton discrepancy is greater in Class III cases than in the other malocclusion groups. Sperry et al,[32] studying the prevalence of the tooth size discrepancy in malocclusion groups, found that Class III subjects showed greater mandibular tooth size excess than the Class II and I groups did. Crosby and Alexander[30] analyzed 109 orthodontic patients, comparing the occurrence of the Bolton ratio tooth size discrepancies among malocclusion groups, but did not include Class III subjects. The results of the study showed no differences in the incidence of tooth size discrepancies among the groups. Cua-Benward et al[33] studied the prevalence of missing teeth in different malocclusion groups, relating their findings to Moss's functional matrix concept. They found a greater prevalence of tooth deformities in the maxilla in Class III individuals, whereas they found more tooth deformities in the mandible in Class II individuals.

Sassouni[34] was the first to report that individuals with a Class III facial type and deficient maxillary growth showed a greater prevalence of alterations in shape of the anterior teeth as well as a greater incidence of agenesis.

In a recent article, Nie and Lin[14] found significant differences in the Bolton ratio among several occlusal categories. The study was performed in 360 Chinese subjects, and the data were analyzed according to Angle classifications Classes I, II, and III as well as according to skeletal type. They concluded that the Bolton anterior ratio was greater in Class III patients than in Class II and Class I subjects.

Bolton,[20,24] in his studies, used ±1 SD to evaluate anterior discrepancies. Although our study analyzes the prevalence of tooth size discrepancies for ±1 SD and ±2 SD, its objective is to revisit the Bolton anterior tooth size analysis and obtain data for anterior dental proportions for ±1 SD in different malocclusion groups.

MATERIALS AND METHODS Return to TOC

The data for this study were obtained from the records of the Catholic University Graduate Program in Orthodontics in Bélo Horizonte, Brazil. Considering that tooth size is not related to age, the sample selection procedure was based on dental age and the presence of a permanent dentition defined by the presence of all teeth at least from first molar to first molar. The sample consisted of 300 patients who lived in Belo Horizonte, Brazil. The subjects were randomly selected and assigned to three malocclusion groups according to the Angle classification Classes I, II, and III. The skeletal pattern was assessed by the Sassouni cephalometric analysis and the ANB angle. Each group comprised 100 individuals with the following distribution: Class I, 42 males and 58 females; Class II, 52 males and 48 females; and Class III, 51 males and 49 females.

The selection criteria were as follows:

- Equivalent skeletal and dental classifications;
- All anterior permanent teeth erupted in the upper and lower arches;
- Good-quality study casts;
- Absence of tooth deformity;
- No record of restoration or stripping of incisor and canine teeth.

Each canine and incisor tooth was measured at the largest mesiodistal dimension using a digital caliper accurate to 0.01 mm. The

reading was recorded at the 0.1-mm level, and the same examiner made all measurements. An analysis of error was performed by remeasuring the study casts of 29 randomly selected individuals and submitting the data to nonparametric Wilcoxon statistical testing.

The anterior tooth size ratio was computed for each subject as described by Bolton[20]:

$$\frac{\text{Sum mandibular 3-3}}{\text{Sum maxillary 3-3}}$$

To statistically compare the prevalence of anterior tooth size discrepancies among the three malocclusion groups and two genders, a chi-square test was performed. Analysis of variance (ANOVA) was used to compare the mean Bolton anterior tooth size ratios as a function of Angle classification as well as gender. Statistical differences were determined at the 95% confidence level ($P < .05$).

RESULTS Return to TOC

Analysis of error

The same investigator performed all measurements, and the reproducibility of the method was tested. A total of 29 individuals (10 Class I, 9 Class II, and 10 Class III) were randomly selected from the original sample, and measurements were repeated twice within a three-week interval. No significant differences between the two sets of measurements ($P > .05$) (Table 1) were found upon testing using the Wilcoxon nonparametric test.

Individual tooth analysis

To accurately collect the data, each tooth was measured at the largest mesiodistal dimension using a digital caliper accurate to 0.01 mm. Mean individual tooth sizes were then compared using ANOVA to determine whether tooth size was related to gender, malocclusion classification, or both. No significant differences were found among the three groups when individual tooth size was compared as a function of Angle classification. Statistically significant differences ($P < .05$) were observed when individual tooth size was compared as a function of gender.

Prevalence of tooth size discrepancy

With the objective of comparing the results of this study with those presented by Bolton,[20] the data were classified as “normal” for Bolton ratios within ±1 SD (77.2 ± 1.65%) and “discrepancy” for ratios greater that ±1 SD.

A total of 56% of the subjects in this study presented Bolton tooth size discrepancies (greater than ±1 SD). However, no significant differences were observed among the three malocclusion groups ($P > .05$) (Figure 1; Table 2). No significant differences were found in the Bolton tooth size prevalence as a function of gender ($P > .05$) (Figure 2; Table 3).

Tooth size discrepancies greater than ±2 SD (30) were considered to be clinically significant (two to three mm). In the present study, clinically significant discrepancies were found in 22.7% of the sample. When analyzed by Angle classification, there were significantly greater numbers of Class I and Class III subjects with ±2 SD tooth size discrepancy than of Class II ($P < .038$) (Figure 3; Table 4). However, no significant difference was observed between genders (Figure 4; Table 5).

Anterior dental proportions

A two-by-three ANOVA was performed to compare the Bolton anterior ratio as a function of Angle classification, gender, or both (Table 6). A significant ($P < .021$) difference in mean anterior Bolton ratio among the malocclusion groups was found. However, gender alone or in combination with Angle classification was not statistically significant ($P > .05$).

The mean for the anterior Bolton ratio was statistically greater for the Class III sample than for the Class I and Class II samples ($P < .021$), and the Class I and Class II samples showed no significant differences when compared with each other (Table 7). No sexual dimorphism was observed for the anterior ratio in the sample studied ($P > .05$) (Table 8).

Considering the Bolton “normality limits” of ±1 SD, which is represented by 77.2 ± 1.65%, only the Class III group had a mean anterior Bolton ratio value outside of that limit (Figure 5).

DISCUSSION Return to TOC

The importance of tooth size discrepancies in orthodontic diagnosis has been widely reported in the literature and accepted by the orthodontic community because the relationship between the upper and lower anterior dentitions is related to orthodontic finishing excellence.

The prevalence of anterior tooth size discrepancies in this sample was very high and serves as an indicator of how important it is to perform a thorough diagnosis before orthodontic treatment. In this study, we demonstrated that 162 individuals (56%) of a total sample of 300 presented with anterior tooth size discrepancies greater than ±1 SD using the Bolton analysis parameter. This percentage (56%) was considerably higher than that found by Richardson and Malhotra[13] (33.7%) and Bolton[20] (29%), which may be explained by the strong genetic mix of the Brazilian population.

Results of these data analyzed for a ±2 SD Bolton discrepancy (22.7%) coincided with those presented by Crosby and Alexander[30] (22.9%) and were close to the findings of Freeman et al[31] (30%) and Santoro et al[18] (28%).

Although there are reports of the prevalence of tooth size discrepancies, there have been few studies relating these discrepancies with the Angle classification of malocclusion. A significantly greater number of Class I and Class III subjects with at least ±2 SD were found in this sample when compared with Class II subjects. Lavelle[1] speculated that Class III individuals had disproportionally smaller maxillary teeth than Class I and Class II subjects did when maxillary and mandibular dentition sizes were compared, but this was not found in the present study. A part of the results of the present study is consistent with the results of Crosby and Alexander,[30] who also found no statistically significant differences when comparing Class I and Class II subjects. However, it is important to remember that Lavelle[1] did not study the Bolton proportions and that Crosby and Alexander[30] did not evaluate Class III patients in their study.

The results obtained by Nie and Lin[14] after analyzing 360 Chinese individuals for tooth size discrepancies using Angle classification as a variable are in agreement with the results of this investigation. Data from both these studies found that Class III patients demonstrate greater tooth size discrepancy when compared with patients of Classes II and I. These findings also corroborate the initial investigations by Sperry et al.[32]

It has been suggested that mesiodistal lateral incisor tooth size is smaller in Class III subjects and serves as an explanation of anterior Bolton tooth size discrepancy. In this study, however, individual tooth sizes were compared, and no differences were discovered in lateral incisor size among the three study groups. Therefore, the Bolton discrepancy in the Class III sample must be attributed to the accumulation of minor discrepancies of individual teeth.

The finding that individuals with Class III malocclusion present with proportionately discrepant maxillary dental arches is important to the clinician who is concerned about accurate diagnosis and treatment planning. When aware of possible discrepancies, the orthodontist will be able to anticipate prosthetic work such as composite buildups or mesiodistal reduction when required, and finishing orthodontics can be better predicted. As stated by Ramos et al,[26] changes in dental inclinations may be used as an orthodontic treatment strategy to resolve anterior Bolton discrepancies and achieve an ideal relationship of incisors. Clinicians should consider increasing the maxillary tooth size mass in Class III patients with the objective of achieving optimal incisor inclinations and occlusion relationships of the anterior dentition.

In this study, no statistical differences in Bolton ratios were found as a function of gender. These findings are in agreement with those reported by other investigators.[13–15,18] The results of this study from data collected in Belo Horizonte, Brazil, are similar to those of the investigation involving African-Americans[13] but differ greatly from the results of white Anglo-Saxonic samples.[7] The diversity of the Brazilian ethnical background is probably responsible for the similarity of the results.

CONCLUSIONS Return to TOC

On the basis of the conditions of this investigation, the following summarizes the important issues of the study:

- Individuals with Angle Class I and Class III show significantly greater prevalence of tooth size discrepancies than do individuals with Class II.
- Mean anterior tooth size discrepancy for Angle Class III subjects was significantly greater than for Class I and Class II subjects.
- The great diversity and possible ethnic mix of current populations should alert the orthodontist to use the Bolton analysis and become aware of moderate variations that may be present and treated.

The orthodontist who is cognizant and aware of these possible discrepancies will be better prepared to diagnose and plan treatment with a more accurate certainty for patients of varied population mix. These conclusions could greatly influence clinical decision-making, and further studies should be undertaken in this field.

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TABLE 1. Analysis of Error for All Measurements Submitted to Nonparametric Wilcoxon Statistical Testing Demonstrating No Significant ($P > .05$) Difference Between the Two Sets of Measurements

Group	Measurement	Descriptive Measurements n	Minimum	Maximum	Mean	SD	*P*
Class I	1	10	74.0	82.0	78.2	2.6	.760 (1 = 2)
	2	10	75.2	83.0	78.4	2.6	
Class II	1	9	73.5	83.9	78.0	2.8	.155 (1 = 2)
	2	9	74.5	83.9	78.9	2.9	
Class III	1	10	75.8	80.0	78.2	1.4	.838 (1 = 2)
	2	10	75.9	80.2	78.2	1.3	

TABLE 2. Results of Chi-Square Testing Demonstrating No Significant Differences ($P = .139$) in the Prevalence of ±1 SD Bolton Tooth Size Discrepancy Among Angle's Classification Groups

Bolton Ratio	Angle Class I n	%	Angle Class II n	%	Angle Class III n	%	Total	%
Normal	46	46.0	53	53.0	39	39.0	138	44
Discrepancy	54	54.0	47	47.0	61	61.0	162	56
Total	100		100		100		300	100

TABLE 3. Results of Chi-Square Testing Demonstrating No Significant Difference ($P = .12$) in the Prevalence of ±1 SD Bolton Tooth Size Discrepancy Between Genders

Anterior Ratio	Gender				Total
	Female		Male		
	n	%	n	%	
Normal	78	50.3	60	41.4	138
Discrepancy	77	49.7	85	58.6	162
Total	155		145		300

TABLE 4. Results of Chi-Square Testing Demonstrating Significant Difference (P = .04) in the Prevalence of ±2 SD Bolton Tooth Size Discrepancy When Angle Class II Was Compared With Either Angle Class I or Angle Class III

Anterior Ratio	Classes						Total	
	I		II		III			
	n	%	n	%	n	%	n	%
Normal	72	72.0	86	86.0	74	74.0	232	77.3
Discrepancy	28	28.0	14	14.0	26	26.0	68	22.7
Total	100		100		100		300	

TABLE 5. Results of Chi-Square Testing Demonstrating No Significant Difference (P = .43) in the Prevalence of ±2 SD Bolton Tooth Size Discrepancy Between Genders

Anterior Ratio	Gender				Total
	Female		Male		
	n	%	n	%	n
Normal	117	75.5	115	79.3	232
>2 SD Discrepancy	38	24.5	30	20.7	68
Total	155		145		300

TABLE 6. Results of Analysis of Variance for Bolton's Anterior Ratio (±1 SD) Among Malocclusion Groups and Gender Demonstrating Significant Difference (P < .021) Among Malocclusion Groups, No Significant Difference Between Genders (P = .784), and No Significant Difference for the Interaction of Gender and Angle Classification (P = .943)

	F	P	
Gender	0.08	.784	Nonsignificant
Classes	3.91	.021	Significant
Gender × classes	0.06	.943	Nonsignificant

TABLE 7. Results of Analysis of Variance (ANOVA) for Bolton Anterior Ratio Discrepancy Demonstrating a Significant Difference (P < .021) for the Class III Group As Compared With Class I or Class II Groups

Classes	Range	Mean	SD	ANOVA
I	72.71–88.08	78.18	2.85	
II	72.91–83.33	78.16	2.21	III > (1 = II)
III	74.08–86.26	79.03	2.35	P < .021

TABLE 8. Results of Analysis of Variance (ANOVA) for Bolton Anterior Ratio Discrepancy Demonstrating No Significant Difference (P < .784) Between Genders

Gender	Range	Mean	SD	ANOVA[a]
Female	72.86–86.26	78.41	2.49	
Male	72.71–88.08	78.50	2.53	$P < .784$

[a] Level of significance of ANOVA is $P < .05$.

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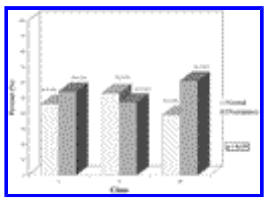

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FIGURE 1. Results of Chi-square testing demonstrating no significant differences ($P = 0.139$) in the prevalence of ±1 SD Bolton tooth size discrepancy among Angle's classification groups

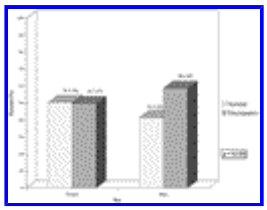

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FIGURE 2. Results of Chi-square testing demonstrating no significant difference ($P = 0.12$) in the prevalence of a ±1 SD Bolton tooth size discrepancy between genders

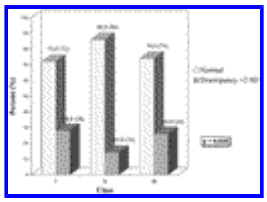

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FIGURE 3. Results of Chi-square testing demonstrating significant difference ($P = 0.04$) in the prevalence of a ±2 SD Bolton's tooth size discrepancy when Angle Class II was compared to either Angle Class I or Angle Class III

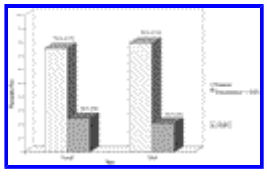

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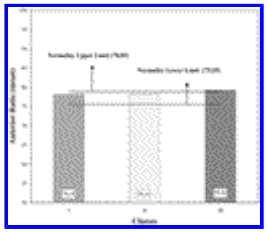
FIGURE 4. Results of Chi-square testing demonstrating no significant difference ($P > .05$) in the prevalence of a ±2 SD Bolton tooth size discrepancy between genders



Click on thumbnail for full-sized image.

FIGURE 5. A comparison of the Bolton anterior discrepancy (mean) in each Angle classification group with the Bolton "normality limits"—77.2% ± 1.65%—demonstrating only the Class III group mean exceeding the +1 SD limit

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