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EVALUATION OF MAXILLARY AND MANDIBULAR RIGHT AND LEFT SIDE TOOTH SIZE DISCREPANCIES IN AVERAGE AND HIGH BOLTON GROUPS

NORMAL VE YÜKSEK BOLTON GRUPLARINDA MAKSİLLER VE MANDİBULAR SAĞ VE SOL DİŞ BOYUT FARKLARININ DEĞERLENDİRİLMESİ

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ABSTRACT

Objective: Evaluating the effects of maxillary and mandibular right and left side tooth size discrepancies on achieving dental midline symmetry and favorable orthodontic occlusion.
Materials and Method: 90 pretreatment dental casts, selected randomly and in permanent dentition, were grouped according to the Bolton analysis as Average Bolton Group (ABG; n:67) and High Bolton Group (HBG; n:23). To designate the left and right dentition size asymmetries and calculate the mesiodistal width of the mandibular and maxillary teeth, a digital caliper was used on orthodontic casts. The hypothesis was tested using a statistical hypothesis test. To statistically compare ABG and HBG groups, the independent samples "t" test was used. The results were evaluated at a significance level of p<0.05.
Results: The difference between the total width of the upper right and left dentition was 0.65±0.55 mm (p<0.05) and the difference between the width of the lower right and left dentition was 0.55±0.49 mm (p<0.05) in the ABG, while in HBG the difference between the sum of the upper right and left dentition was 0.55±0.39 mm (p<0.05) and the difference between the sum of the lower right and left dentition was 0.53±0.43 mm (p<0.05). There were no statistically significant differences between the ABG and HBG (p>0.05) according to the independent samples "t" test.
Conclusions: The results indicated that there are minimal but statistically significant differences between the right and left mesiodistal tooth width totals both in ABG and HBG that should be considered to attain favorable orthodontic treatment results and dental midline symmetry.

Key Words: Bolton analysis, average bolton, high bolton, dental asymmetry, tooth size discrepancy

ÖZ

Amaç: Maksiller ve mandibular sağ ve sol diş boyutlarındaki uyumsuzlukların dental ve orta hat simetrisini sağlama ve uygun ortodontik oklüzyon elde etme üzerindeki etkisini değerlendirmektir.
Gereç ve Yöntem: Ortodontik tedavi öncesi daimi dentisyondaki 90 alçı model rastgele seçilmiş ve Bolton analizine göre Normal Bolton Grubu (NBG; n:67) ve Yüksek Bolton Grubu (YBG; n:23) olarak sınıflandırılmıştır. Maksiller ve mandibular dişlerin meziodistal genişliğini ölçmek ve aralarındaki sol ve sağ diş boyutu asimetrilerini belirlemek için doğrudan alçı modellerden dijital kumpas ile ölçümler yapılmıştır. Hipotezi test etmek için İstatistiksel Hipotez Testi kullanılmıştır. NBG ve YBG'yi istatistiksel olarak karşılaştırmak için Bağımsız Gruplar "t" testi kullanılmıştır. Sonuçlar p<0.05 anlamlılık düzeyinde değerlendirilmiştir.
Bulgular: İstatistiksel hipotez testi sonuçlarına göre, NBG'de üst sağ ve sol dişlerin toplamı arasındaki farkın 0.65±0.55 mm, alt sağ ve sol dişlerin toplamı arasındaki farkın ise 0.55±0.49 mm (p<0.05) bulunurken, YBG'de üst sağ ve sol diş genişliği arasındaki fark 0.55±0.39 mm (p<0.05) ve alt sağ ve sol diş genişliği arasındaki fark 0.53±0.43 mm (p<0.05) olarak bulunmuştur. Bağımsız gruplar "t" testi sonucunda, NBG ve YBG arasında istatistiksel olarak anlamlı bir farklılık bulunmamıştır (p>0.05).
Sonuç: Bolton analizi, ideal bir oklüzyon elde etmek için üst ve alt diş boyut uyumsuzluklarını ve oranlarını ifade ederken, bir ortodontik tedavi planında sağ ve sol yarım arklardaki diş boyutu farklılıkları çoğunlukla göz ardı edilmektedir. Sonuçlar hem ABG hem de HBG'de sağ ve sol meziodistal diş genişliği toplamları arasında, uygun ortodontik tedavi sonuçları ve dental orta hat simetrisi elde etmek için dikkate alınması gereken minimal ancak istatistiksel olarak anlamlı farklılıklar olduğunu göstermiştir.

Anahtar Kelimeler: Bolton analizi, yüksek bolton, normal bolton, dental asimetri, diş boyutu uyumsuzluğu

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INTRODUCTION

The main goals of orthodontic treatment are balanced and ideal occlusal relationship and function, dentofacial aesthetics, and long-term stability (1). Ideal occlusion can be defined as occlusion in which centric occlusion is accompanied by a centric relationship, effective chewing, and ideal aesthetics are provided within physiological limits and in harmony with the stomatognathic system (2). In most orthodontic patients, since the discrepancies in the dimensions of the teeth do not allow the teeth to be aligned properly in the dental arch and the ideal occlusal relationship to be formed, these goals are challenging to achieve and require personalized ideal treatment planning (1).

Dental crowding is one of the most common clinical findings seen in orthodontic patients. The causes of dental crowding include developmental incompatibility between the lower and upper jaws, early loss of primary teeth, incompatibility between the mesiodistal diameters of the teeth and arch length of the teeth, functional disorders in the oral and perioral muscles, bad habits and supernumerary teeth (3). Methods that appear as current principles to solve the crowding are transverse jaw expansion, proclination of anterior teeth, extraction of premolars and/or other teeth, intra-arch distalization of teeth, and interproximal enamel reduction.

It has been emphasized that tooth size discrepancy is one of the critical causes of crowding and orthodontic malocclusion, and this discrepancy in tooth dimensions should be eliminated by extraction or interproximal enamel reduction (4). An orthodontically ideal occlusion is a complete orthodontic occlusion when the ratio of the sum of the mesiodistal diameters of the upper and lower 12 teeth determined by Bolton model analysis during orthodontic treatment planning is compatible at the beginning (91.3±1.9%) and end (91.3±1.9%) treatment (5). Angle Class I relationship can be obtained with cusp-embrasure relationship, overjet, and overbite relationship. Values outside this ratio are an indicator of excess or lack of dental material in the lower or upper dental arch. As a result, it is not possible to reach the optimum overjet, overbite, and Class I canine and molar relationship at the end of orthodontic treatment in patients with tooth size discrepancy.

Tooth size ratios and occlusion

Studies on tooth size and morphology date back to the early 1900s. G.V. Black was the first to work with tooth dimensions; he measured tooth dimensions and developed tables that are still used today (Figure 1) (6). One type of orthodontic irregularity is tooth size discrepancies. Bolton defined these discrepancies as individual disproportions between tooth sizes (7).

In 1923, Young suggested for the first time that the overbite, especially the deep bite, is affected by the size relationship of the upper teeth to the lower teeth (8). According to Young's study, excessive tooth size in the upper teeth causes deep bites, and excessive tooth size in the lower teeth causes insufficient bite.

In the 1940s, Wheeler published a textbook called Dental Anatomy and Physiology, which has survived to the present day (9). In this book, he investigated the average tooth sizes necessary for the teeth to be placed in the ideal position possible as a result of the measurements he made on a large number of skulls.

Lundstrom examined 319 individuals aged 13 years, randomly selected in 1954 regarding occlusion characteristics, and reported a variation between the mesiodistal widths of the upper and lower teeth (8). Lundstrom created three different tooth size ratios and emphasized that deviations in those particular ratios would affect tooth position, overbite, and overjet (8).

Today, the most well-known tooth size analysis in the orthodontic literature is the analysis by Wayne A. Bolton regarding the mesiodistal tooth size ratios between teeth in the mandible and maxilla (7). While creating its formula, a total of 55 patients, 44 of who had orthodontic treatment without extraction and 11 of whom were untreated, with perfect Angle Class I canine and molar relationships were evaluated and reported at two rates. The total ratio (12 teeth ratio) and the anterior ratio (6 tooth ratio) were obtained by dividing the sum of the mesiodistal widths of the lower anterior six teeth by the sum of the mesiodistal widths of the upper anterior six teeth.

As a result of this procedure, the mean and standard deviation values obtained for the total ratio were 91.3±1.91 and 77.2±1.65 for the anterior ratio. This ratio is defined as the 'Bolton Ratio.' It has been reported that "Bolton Discrepancy" will occur when this harmony between the upper and lower teeth is disrupted. This study concluded that unless the average ratio was obtained between the mesiodistal dimensions of the upper and lower teeth, a suitable occlusal relationship could not be achieved at the end of orthodontic treatment (7).

$$\text{Total Ratio} = \frac{The\ Sum\ of\ mandibular\ 12}{The\ Sum\ of\ Maxillary\ 12} x100$$

$$Anterior\ Ratio = \frac{The\ Sum\ of\ Mandibular\ 6}{The\ Sum\ of\ Maxillary\ 6} x100$$

The Total Bolton ratio of patients in the Average Bolton Group without tooth size discrepancy was 91.3±1.91%, which was determined as the reference range in Bolton's study, and the total Bolton ratio of patients in the High Bolton Group was greater than 93.21%. Anterior Bolton Ratio was accepted as 77.2±1.65%; the Anterior Bolton ratio of patients in the High Bolton Group was considered greater than 78.85% (7).

Dental midline deviations

Dental midline deviations generally occur due to the posterior crossbite, early loss of deciduous teeth, arch asymmetries, tooth size discrepancies, congenitally missing teeth (retained primary tooth), ankylosis of primary molars, supernumerary teeth, and habits (10-13).

Becker stated that posterior teeth positioned lower than the bite plane (infra-occlusion) may also cause midline deviations

(14). It is suggested that the reason for this is the stretching of the transseptal fibers on the tooth side in infra-occlusion. Loss of one or two primary teeth on the same side or loss of two primary teeth on one side and one primary tooth on the other side also causes deviations in the midline. Dental midline deviations are also observed in unilateral congenital tooth deficiencies or agenesis and the presence of a supernumerary tooth (10-13).

In cases where the face is symmetrical, four different dental midline deviations may be encountered (13):
- The upper dental midline may deviate from the midline of the face.
- The lower dental midline may deviate from the midline of the face.
- Concerning the midline of the face, the upper dental midline may be on one side and the lower dental midline on the other.
- The midlines of the dental arches of both jaws may overlap and deviate from the midline of the face.

A major factor in coordinating symmetry, posterior interdigitation, overbite, and overjet in neutrocclusion is the relative harmony in mesiodistal width of the maxillary and mandibular dentitions (28). The importance of this geometric relationship becomes apparent to orthodontists, especially in the finishing stages of a treated case (15).

This study aims to evaluate the effects of mandibular and maxillary right and left semi-arch's tooth size discrepancies on establishing midline symmetry. The null hypothesis of this study is that the sum of maxillary and mandibular right and left side semi-arch dentition widths is equal.

MATERIAL AND METHODS

In our study, 4927 pretreatment orthodontic dental casts taken from patients in Istanbul University Faculty of Dentistry Department of Orthodontics between 2010 and 2015 were examined. Dental casts were selected according to the following inclusion criteria:
1. Permanent and fully erupted dentition, including second molars
2. Clearly selectable anatomical contours of all teeth
3. Permanent dentition with 6 to 8 mm of crowding both in upper and lower arches
4. Absence of dental fillings on all dental casts
5. Absence of dental caries on all dental casts
6. No broken teeth on all dental casts
7. Absence of severe mesio-distal or occlusal tooth wear on dental casts
8. Absence of teeth with crown and/or bridge prosthesis applied on dental casts
9. Absence of congenital tooth deficiency or shape anomaly on all dental casts

To calculate the estimated sample size, a power analysis was performed using G*-power 3.1.9.2 software with effect size 0.4858, standard deviation 1.3 (alpha error probability: 0.05), and power of 0.8. The results yielded 60 minimum orthodontic subjects (16).

Ninety pretreatment orthodontic dental casts that met the inclusion criteria were selected randomly. They were grouped according to the Bolton analysis as Average Bolton Group (ABG; n:67) and High Bolton Group (HBG; n:23) as shown in Figure 1.

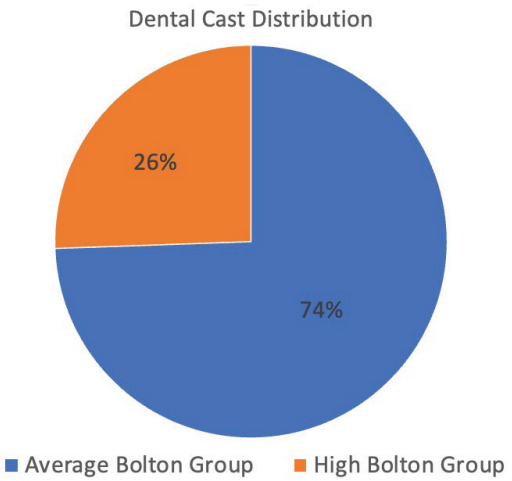


Figure 1: Dental Cast Distribution among Average and High Bolton Groups

The criteria for the formation of the Average and High Bolton Group are shown in Table 1 and Table 2 below.

Table 1: Criteria for the formation of the Average and High Bolton Groups according to the Independent Samples "t" test -Total Bolton Ratio ±

Ideal total ratio	Average Bolton Group (n=67)	High Bolton Group (n=23)	IB/ AB	IB/ HB
91.3%±1.91	91.71±1.28	95.28±0.89	NS	*

NS: Not Significant, IB:Ideal Bolton, AB: Average Bolton, HB: High Bolton, *: p<0.001

Table 2: Criteria for the formation of the Average and High Bolton Groups according to the Independent Samples "t" test - Anterior Bolton Ratio

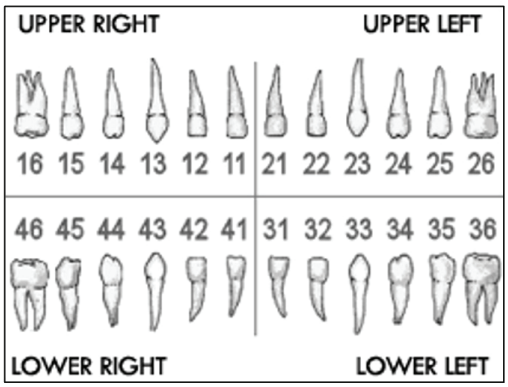
Ideal anterior ratio	Average Bolton Group (n=67)	High Bolton Group (n=23)	IB/ AB	IB/ HB
77.2%±1.65	78.79±2.00	81.07±2.32	NS	*

NS: Not Significant, IB: Ideal Bolton, AB: Average Bolton, HB: High Bolton, *: p<0.001

The null hypothesis of this research is that the sum of maxillary and mandibular left and right-side dentition widths is equal (Figure 2).

Measurements were performed manually with a digital caliper (Mitutoyo Digimatic Caliper, Japan, model no-500-196-30 CD-6' ASX) directly on orthodontic casts to measure the maxillary and mandibular 6-6 teeth' mesiodistal widths and identify the right and left tooth size discrepancies among them (Figure 3).

$$\sum_{i=11}^{16} MD\ width_i \overset{?}{=} \sum_{i=21}^{26} MD\ width_i$$



$$\sum_{i=41}^{46} MD\ width_i \overset{?}{=} \sum_{i=31}^{36} MD\ width_i$$

Figure 2: Mesiodistal sums of both maxillary and mandibular semi-arches (17)

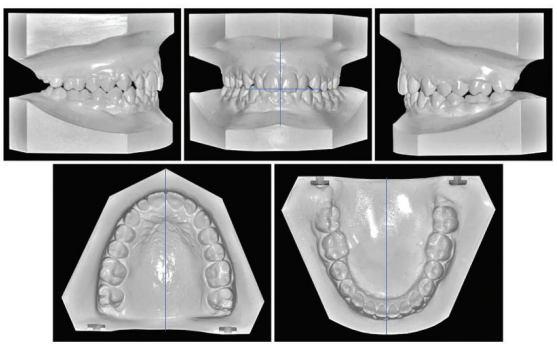


Figure 3: Dental cast samples (18)

To determine the reproducibility and reliability of the measurements, the tooth size values of each dental cast analyzed within the scope of the present study were measured again with a digital caliper 15 days after the first measurements by the same researcher (F.H.A.) (Table 3).

The statistical analyses were performed in this study using the NCSS (Number Cruncher Statistical System, Utah, USA) 2007 statistical software package program. To test the null hypothesis, which states both Average and High Bolton groups have identical mesiodistal teeth widths on both the right and left side, a "Statistical hypothesis test" was used. To compare Average and High Bolton groups statistically, besides descriptive statistical methods (averages, standard deviation), the independent samples "t" test was also used. The results were evaluated at a significance level of $p<0.05$, with a 95% confidence interval.

RESULTS

The results of method error checking for repeatability of dental cast measurements are shown in Table 3. As can be seen in the table, the reliability coefficient values (Intraclass Correlation Coefficient) were found over 0.700 (0.965-0.998) in all measurements. The fact that the reliability coefficients were very close to the exact value of 1.00 showed that the measurements could be repeated with a statistically insignificant error.

Table 3: The Results of the Method Error by using the Intraclass Correlation Coefficient (ICC)

		Intraclass Correlation Coefficient (ICC)	95% confidence interval
All Groups	Total Ratio	0.993	0.989-0.995
	Anterior Ratio	0.992	0.987-0.994
Average Bolton Group	Total Ratio	0.984	0.973-0.990
	Anterior Ratio	0.968	0.923-0.987
High Bolton Group	Total Ratio	0.988	0.980-0.992
	Anterior Ratio	0.996	0.990-0.998

In Average Bolton Group: The average value was found to be 0.097 mm for the upper right and left dentition's mesiodistal width difference. The average value was found to be 0.003 mm for the lower right and left dentition's mesiodistal width difference. The upper right and left dentition's mesiodistal width difference was found to be 0.65±0.55 mm ($p<0.05$), and the lower right and left dentition's mesiodistal width difference was found 0.55±0.49 mm ($p<0.05$) (Figure 4).

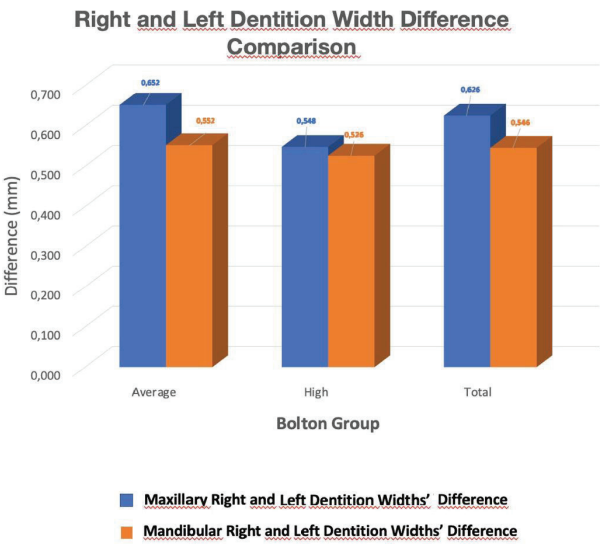


Figure 4: Maxillary and Mandibular Right and Left Dentition Width Difference Comparison according to the independent samples "t" test

In the High Bolton Group: The average value was found to be 0.19 mm for the upper right and left dentition's mesiodistal width difference. The average value was found to be -0.083 mm for the mesiodistal width difference between the lower right and left dentition. The upper right and left dentition's

mesiodistal width difference was 0.55±0.39 mm (p<0.05), and the lower right and left dentition's mesiodistal width difference was 0.53±0.43 mm (p≤0.05) (Figure 4).

There are no statistically significant differences between the Average Bolton Group and High Bolton Group according to the independent samples "t" test shown in Figure 2 (p>0,05).

DISCUSSION

In most orthodontic patients, treatment goals are challenging to achieve because the discrepancies in tooth sizes do not allow the teeth to be aligned properly in the dental arch and to form an ideal occlusal relationship. In 1958, Bolton determined the average total and anterior ratio values required for an ideal lower and upper occlusal relationship (7). Today, it has become a reference for researchers and clinicians concerning treatment planning. The absence of tooth size discrepancy has been identified as the seventh key to ideal occlusion (1). In patients with intra-arch tooth size discrepancy, some material removal from the teeth (interdental enamel reduction) or the addition of some restorative material to the tooth is required to open some space up or close space in the opposite arch. Therefore, it is crucial to determine the amount and location of tooth size discrepancy during the pretreatment phase (1,2,7).

In our study, with the help of a digital caliper on dental casts, the mesiodistal widths of 12 teeth in each of the upper and lower dental arches- from the distal of the first molar to the distal of the other first molar- were calculated. Asquith et al. reported that the difference between the measurements made on the digital model and dental plaster casts was less than 0.5 mm, which was not clinically significant (10, 19). Similarly, Quimby et al. reported that measurements made with digital methods were larger than the measurements made on dental plaster casts (19). Although the difference was small, it was statistically significant but not clinically. It was reported that digital methods could be used besides the measurements on the dental casts being more reliable. Santora et al. also reported that digital measurements were smaller in their research, in which they compared the measurements made on the digital casts and dental plaster casts (20). It has been reported that the difference between the measurements is due to the shrinkage that occurs in the alginate during the transfer of the alginate impression taken to the company. In three-dimensional imaging, the measurements carried out between the selected points by enlarging the contact points may vary depending on the person's clinical experience. Another method used to measure tooth dimensions is the direct intraoral measurement which has been compared with dental cast measurements by researchers in the past years. In those studies, it was stated that the differences between the results of the two methods were insignificant (21-22). In conclusion, considering the cost of the measurements, our retrospective study was done on dental plaster casts since there is no scientifically significant difference between dental plaster casts, digital measurement, and intraoral direct measurement methods.

All Bolton analyses are conducted according to the assumption that the sum of maxillary and mandibular left and right-side dentition widths is equal. Many researchers focused on the effects of lower and upper teeth ratios on malocclusion in their studies; however, there is a limited number of studies in the literature comparing the sizes of the right and left teeth width on both arches. While some investigators reported significant differences between right and left tooth sizes, some investigators reported that difference was not statistically significant (22,23,27-33). In a study conducted by Ballard et al. with 500 models, it was found that in 90% of cases, there was a tooth discrepancy between the right and left teeth, not less than 0.25 mm and not more than 0.50 mm (34). Lysell and Myrberg reported a difference between right and left tooth sizes in the examination of 580 female and 530 male individuals with primary and permanent dentition models, while Lundström reported that the right and left differences were insignificant in their measurements (8, 35). Garn et al. on the other hand, suggest that asymmetry is more common in the last tooth of each morphological class, and this is more common in cases with congenital third-molar deficiency (36). In our study, we found a significant difference between right and left tooth size, both in the Average and High Bolton groups. The mean Bolton value measured in the Average Bolton group was 1.11±0.67 mm, and 3.72±0.90 mm in the High Bolton group in our study. In the Average Bolton Group, although there was no significant tooth size discrepancy that prevents ideal occlusion, the difference between the mesiodistal width of the upper right and left semi-arch was found 0.65±0.55 mm (p<0.05) and the difference between the mesiodistal width of the lower right and left semi-arch was 0.55±0.49 mm (p<0.05). To provide dental symmetry, interproximal enamel should be reduced to both maxillary and mandibular right semi-arch teeth accordingly to the excessive tooth materials. In the High Bolton Group, besides the 3.72±0.90 mm tooth size discrepancy, the upper right and left dentition's mesiodistal width difference was 0.55±0.39 mm (p<0.05), and the difference between the width of the lower right and left dentition was 0.53±0.43 mm (p<0.05). To avoid dental asymmetry and equalize right and left tooth size sums, interproximal enamel reduction or tooth extraction must be done accordingly to the right and left tooth width difference.

CONCLUSION

The null hypothesis was rejected. The results of this study showed both in the Average and High Bolton Group, there were minimal but statistically significant differences between the patient's right and left mesiodistal tooth width totals that must be considered to attain favorable orthodontic treatment results and dental midline symmetry.

To estimate an ideal occlusion, orthodontists refer to Bolton analysis which shows upper and lower tooth size discrepancies. However, tooth size asymmetries on the right and left sides of the dental arch have frequently been underestimated in an orthodontic treatment plan. This difference between right and left dental semi-arches should be considered to obtain ideal orthodontic treatment results and dental midline symmetry.

The difference in the mesiodistal widths of the right and left teeth prevents inter-arch and intra-arch symmetry even if Bolton values are provided. In addition to the Bolton values, the

widths of the right and left teeth should also be calculated and included in orthodontic treatment planning to ensure dental symmetry.

If there is significant asymmetry in the widths of the maxillary or mandibular right and left teeth, stripping large teeth and placing veneers/composite restorations on small teeth will provide symmetry.

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