# The Application of Bolton's Ratios in Orthodontic Treatment Planning for Chinese Patients

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**Abstract:** *Aim:* To investigate the application of Bolton's ratios in the proper diagnosis and treatment planning for Chinese orthodontic patients with congenitally missing mandibular incisor.

*Materials and Methods:* Twenty-seven Chinese cases (males 10, females 17) with congenitally missing mandibular incisor and class I molar relationship were recruited in this study. Guided by the anterior Bolton's ratios, three therapeutic strategies (each for 9 patients) were carried out according to different indications, which included enamel stripping, prosthetic restoration and extraction therapy.

*Results:* After treatment, all the patients achieved good occlusion with normal Bolton's ratios and the clinical results were satisfied.

*Conclusion:* It suggested that the application of Bolton's ratios in orthodontic treatment planning for Chinese patients with mandibular congenital missing incisor might be clinically beneficial for optimum treatment outcomes.

**Keywords:** Bolton's ratios, Chinese orthodontic patients, congenitally missing teeth.

## INTRODUCTION

It is important to establish an optimum balance between the mesiodistal tooth sizes of the maxillary and mandibular arches in order to ensure ideal interdigitation, overbite, and overjet at the completion of orthodontic treatment [1]. Bolton developed 2 ratios (formulae) for estimating tooth-size discrepancy by measuring the summed mesiodistal widths of the mandibular to the maxillary anterior teeth, which has been widely used in scientific studies and clinical practice (Fig. **1**) [2]. The ideal anterior ratio is expressed as 77.2% when the six anterior teeth are measured, and from the right first molar to the left first molar, the total ratio is 91.3%. The values were named as Bolton's Index and served as an aid in the diagnosis and treatment planning of orthodontic cases and in determining the functional and esthetic outcome. These Bolton's ratios allow the orthodontist to gain insight into the functional and aesthetic outcome of a given case without the use of a diagnostic setup. Clinically, the Bolton's ratios have been used to determine the need for reduction of tooth size by interproximal stripping or the addition of tooth size by prosthetic restoration [3].

The most commonly congenitally absent teeth are the upper lateral incisors in Caucasian populations [4] and the lower incisors in Chinese populations [5]. Davis [5] reported that the missing lower incisors affected 58.7% of the Chinese children with hypodontia. As to the patients with the missing mandibular teeth, the Bolton's ratios definitely decreased, the treatment options could be stripping upper teeth, flaring the lower incisors and moderately increasing the overjet or overbite [6, 7]. However, to the best of our knowledge, there is no study concerning how the Bolton's ratios direct to the orthodontic treatment of Chinese patients with congenitally missing lower incisor.

Therefore, the purpose of this retrospective clinical trial is to establish the proper diagnosis and treatment planning for Chinese patients with congenitally missing mandibular incisor (s) by analyzing the anterior teeth size using the Bolton's ratios. It will be clinically beneficial to achieve a successful occlusion with an optimal overjet and overbite.

## MATERIALS AND METHODS

### Patient Enrollment Criteria

The sample consists of 27 Chinese patients (12 males and 15 females; mean age, 23.5 ± 4.5 years; age range, 19 -28 years) with one congenitally missing mandibular incisor and skeletal Class I. All clinical treatments were performed at the third Affiliated Hospital, School of Stomatology, Fourth Military Medical University. Information was collected from the patients' registration and case history. All of the cases were treated by the standard edgewise orthodontic technique. Before orthodontic treatment, the mesiodistal diameters of tooth sizes were measured by one of the authors using digital calipers from first molar to first molar at the level of contact points. Any case with skeletal deformity or bruxism was excluded. The study protocol was approved by the Ethics Committee of the Fourth Military Medical University and written informed consent was obtained from all cases in accordance with the Helsinki declaration. The treatment options were formulated based on the anterior Bolton's ratios.

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1874-9127/10 2010 Bentham Open

$$\text{Anterior ratio} = \frac{\text{Sum of mesiodistal widths of mandibular six anterior teeth (mm)}}{\text{Sum of mesiodistal withds of maxillary six anterior teeth (mm)}} \times 100$$

$$\text{Overal ratio} = \frac{\text{Sum of mesiodistal widths of mandibular twelve teeth (first molar-first molar) (mm)}}{\text{Sum of mesiodistal widths of maxillary twelve teeth (first molar-first molar) (mm)}} \times 100$$

**Fig. (1).** Bolton's ratios.

### Chinese Anterior Bolton's Ratios

According to the data of crown width of normal Chinese permanent teeth (Table **1**) [8] and the Bolton's formula, Chinese normal anterior Bolton's ratios value is calculated as 0.787 (Fig. **2**).

### Treatment Options

#### *Maxillary Teeth Enamel Stripping*

In this group, the patients were Class I malocclusion with slight crowding in maxillary anterior teeth, protrusion and deep overbite and overjet. For such cases, the mandibular central incisor was congenitally missing, according to the Bolton's analysis resultant formula and the normal Chinese crown width of permanent teeth, the numerator was decreased 5.4mm, then the denominator should be decreased 6.85 mm to maintain the normal Bolton' ratios. The decrease means each surface of ten maxillary teeth, from the right second premolar to the left second premolar, need to be stripped 0.34mm respectively, which indicated by the following formulas (Fig. **3**):

#### *Prosthetic Restoration of Mandibular Tooth*

If the patients showed the limited mandibular development with the straight or slight retrusion profile, the expansion of mandibular dental arch was carried out. To open up the extra space of 5.4mm for the lower central incisor and then replace the missing incisor prosthetically to improve the profile.

#### *Extraction of one Lower Anterior Tooth and Two Upper Premolars*

If the patient showed convex profile, the treatment planning of extraction was considered to improve the profile and correct the shifted midline in lower jaw. One lower central anterior tooth and two upper first premolars were extracted to balance the congenitally missing mandibular incisor. Statistically, the average width of the lower first premolar is 7.1mm in Chinese patients. Therefore, the anterior Bolton ratio after extraction was of 0.860, which was obviously larger than normal value. Correcting the tooth-size discrepancy was completed by interproximal recontouring of the mandibular canines, the incisors, and the mesial surfaces of the first premolars, for a total of 10 surfaces of 0.45mm, 0.35mm, and 0.05mm respectively according to the following formulas (Fig. **4**). Similarly, if two lower incisors were congenitally absent, only two upper first premolars should be extracted.

## RESULTS

Guided by anterior Bolton's ratios, 27 patients with one congenitally missing mandibular incisor were successfully treated. Three therapeutic methods were carried out according to different indications: 14 patients were treated with enamel stripping; 4 with mandibular prosthetic restoratiosn; 9 with extraction of one lower anterior tooth and two upper premolars combined with enamel stripping in lower teeth if necessary. The treatment period was 18 months in average

**Table 1. Chinese Permanent Teeth Crown Width (mm)**

| | Central Incisor | Lateral Incisor | Canine | First Premolar |
|---|---|---|---|---|
| Maxilla | 8.6 | 7.0 | 7.9 | 7.2 |
| Mandible | 5.4 | 6.1 | 7.0 | 7.1 |

$$\frac{\text{Sum mandibular six anterior teeth (mm)}}{\text{Sum maxillary six anterior teeth (mm)}} = \frac{7.0+6.1+5.4+5.4+6.1+7.0}{7.9+7.0+8.6+8.6+7.0+7.9} = \frac{37.0}{47.0} = 0.787$$

**Fig. (2).** The calculation of Chinese anterior Bolton's ratios.

$$\frac{\text{Sum mandibular six anterior teeth (mm)}}{\text{Sum maxillary six anterior teeth (mm)}} = \frac{37.0-5.4}{47.0-x} = 0.787 \quad X=6.85\text{mm}$$

$$\frac{6.85/10}{2} = 0.34\,\text{mm}$$

**Fig. (3).** The calculation for stripping in non-extraction cases.

$$\frac{\text{Sum mandibular six anterior teeth (mm)}}{\text{Sum maxillary six anterior teeth (mm)}} = \frac{37.0 - 5.4 \times 2 + 7.1 \times 2}{47.0} = \frac{40.4}{47.0} = 0.860\,\text{mm}$$

$$\frac{6.1 - 5.4}{2} = 0.35\,\text{mm}$$

$$\frac{7.0 - 6.1}{2} = 0.45\,\text{mm}$$

$$\frac{7.1 - 7.0}{2} = 0.05\,\text{mm}$$

**Fig. (4).** The calculation for stripping in extraction cases.

(from 6 to 24 months). After treatment, all the patients achieved normal Bolton's ratios and satisfactory clinical results.

**Typical Cases**

***Case One (Figs. 5A,B)***

A Chinese female aged 27 years 4 month old, presented with Angle Class I molar and canine relationship; 41 was congenitally missing; the crowding in upper arch was 4mm. Anterior teeth were edge to edge occlusion, lower midline deviated 4mm to the left. The profile was straight. During cast analysis, anterior Bolton ratio was 0.675. Pre-treatment lateral cephalometric analysis showed that the distance of 1 to NA was 8.2 mm, the angle of 1 to NA was 35.4 º, and 1 to 1 was 139 º. The treatment planning was that the teeth from the right second premolar to the left second premolar in maxilla were stripped and the spaces available were used to resolve dental crowding and aligned the dentition. The active treatment period was 12 months. After treatment, the intra-oral examination showed that Angle Class I molar and canine relationships were maintained; anterior overjet and overbite were normal; upper and lower teeth were aligned; except that upper midline was aligned with the lower central incisor's midpoint. Dental cast analysis showed that the anterior Bolton ratio was 0.787. Post-treatment lateral cephalometric analysis showed that the distance of 1 to NA was 4.7 mm, the angle of 1 to NA was 24.5 º, and 1 to 1 was 123.8 º.

***Case Two (Figs. 6A,B)***

A Chinese female aged 19 years 6 months old, presented with Angle Class I molar relationship. The upper canines erupted buccally. 41 was congenitally missing; the crowding in upper arch was 4mm and in lower arch was 5mm and the overjet was 13mm; deep overbite was II degree. Lower midline was deviated 2.5mm to the right. The facial profile was convex with maxilla protrusion. Using cast analysis, the anterior Bolton ratio was 0.673. Pre-treatment lateral cephalometric analysis showed that the distance of 1 to NA was 10.5 mm, the angle of 1 to NA was 34.0 º, and 1 to 1 was 107 º. The treatment plan was extraction of two upper first premolars and left central incisor. The lower lateral incisors, canines and first premolars were enamel stripped as well as the lower central incisors, lateral incisors and canines. The spaces available in upper and lower arches were used to resolve dental crowding and alignment. The active treatment time was 16 months. After treatment, the intra-oral examination showed that Angle Class I molar and canine relationships were obtained; anterior overjet and overbite were normal; upper and lower teeth were aligned; and upper and lower midlines were centred. Dental cast analysis showed that the anterior Bolton ratio was 0.787. Post-treatment lateral cephalometric analysis showed that the distance of 1 to NA was 4.5 mm, the angle of 1 to NA was 22.3 º, and 1 to 1 was 125.6 º.

**DISCUSSION**

Prevalence of congenitally missing teeth is not uncommon. The etiology of congenitally missing teeth is probably due to heredity or familial distribution and a disturbance in the fusion of the embryonic facial development or an evolutionary trend with the reduction in dentition or localized inflammation or infections in the jaw, or disturbance of the endocrine system may have caused an ectodermal dysplasia. [9, 10]. The absence of mandibular incisor (s) initiates series of challenging problems with regard to treatment planning and mechanical therapy. Moreover, most of such patients suffer from mandibular midline deviation or increased in overjet and deep overbite. A tooth size discrepancy greater than 1.6 mm has a considerable impact on the final occlusion [11], a missing mandibular incisor could severely compromise proper overjet, overbite, and Class I canine relationship. All these malocclusions provide a reason for the growing interest in the literature for studying the problem of tooth-size discrepancy. Clearly, it is an important factor to take into consideration for the appropriate orthodontic treatment planning.

Basdra and coworkers [12] suggested that there was close correlation between Angle Class II division 2 malocclusion and congenital tooth development defection. Newman reported three main treatment options [7]: 1) To create the space for the missing mandibular incisor with fixed prosthesis; 2). To extract the maxillary first premolars to balance the mandibular tooth size discrepancy. 3). Consolidate the mandibular incisor spaces by mesially moving the posterior teeth to facilitate correction of the malocclusion. In Newman's opinion [7], there were several shortcomings on space creation for fixed bridge orthodontically, e.g. great difficulty of rehabilitation and long time for interspace maintaining. The interspace had to be kept for 3 years or more till the related


**Fig. (5).** **A**: Pre-treatment photographs of Case One. **B**: Post-treatment photographs of Case One.

tooth was suitable for abutment. It is too long, especially for children to wear a removable retainer. With the continuous eruption of the abutments, new fixed bridge had to be made which increases the economic burden of the patients. However, the extraction of two maxillary premolars would affect the profile of the patients. In that case, his suggestion was to

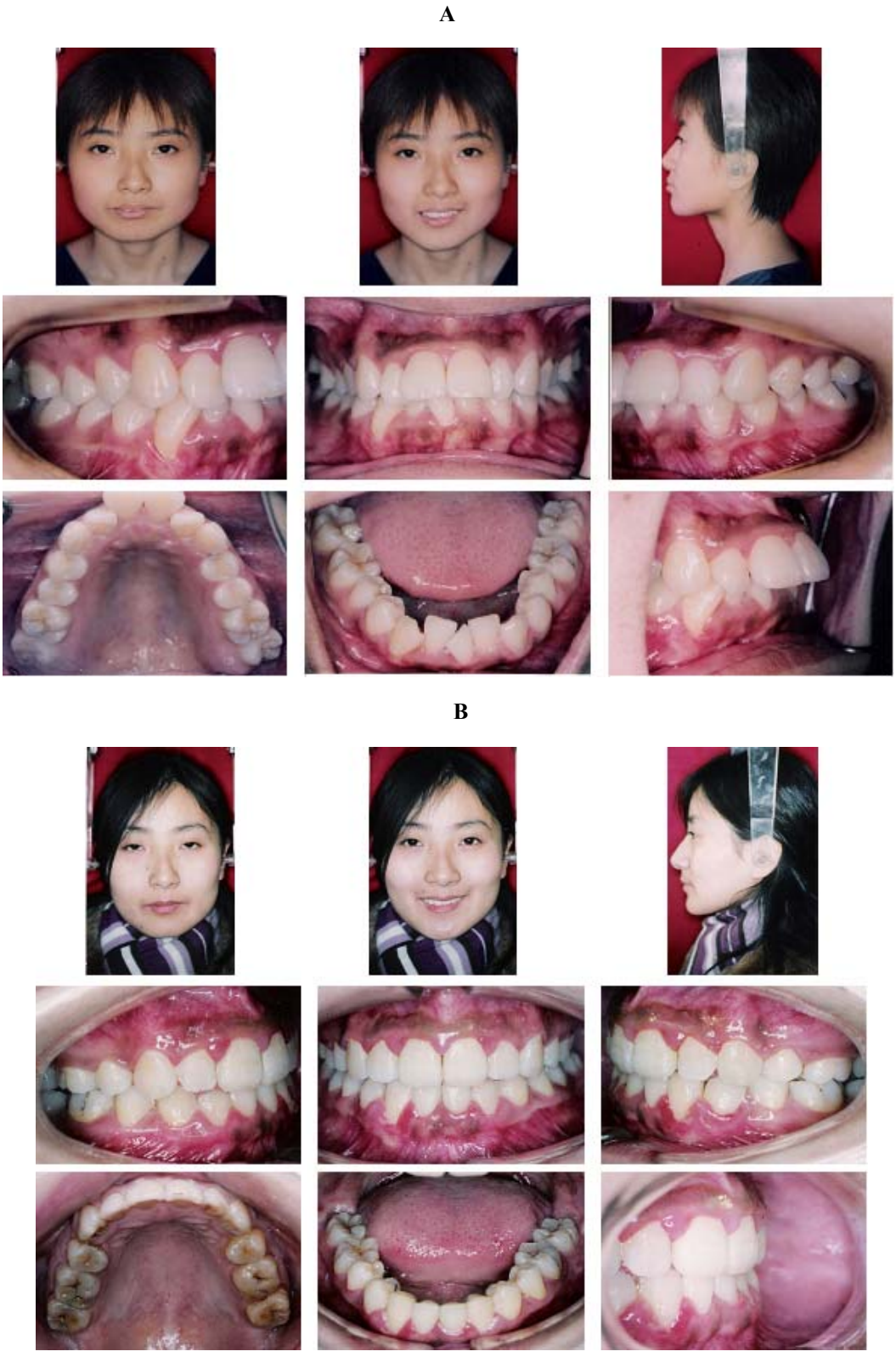


**Fig. (6).** **A**: Pre-treatment photographs of Case Two. **B**: Post-treatment photographs of case two.

select the third method for those who had fairly well profile in order to gain better occlusal relationship.

Bolton's analysis is critically important and it should be taken in considerationsn for better diagnosis, for more specific treatment planning in order to achieve a successful occlusion with an optimal overjet and overbite. On the other hand, the differences in the ethnicity of patient populations must be taken into account. Smith [13] who evaluated the interarch relationships and tooth sizes in three different population

groups and the results show important differences based on ethnicity and gender either in the length of arches or in Bolton's ratios. Furthermore, Alberto Lainothis and colleagues [14] proved that the relationship between the sizes of the upper and lower teeth depends on the ethnicity of the population studies and the gender. All these studies suggested that Bolton's ratio is not universally applicable across all population groups. Therefore, in the present study, we calculated the normal anterior Bolton's ratios value followed by Chinese population tooth width.

The normal anterior Bolton's ratio value in Chinese is 0.787. In the present study, the cases with one congenitally missing mandibular incisor indicate the sum of the lower anterior teeth width was small and decreased, which means the sum of the upper anterior teeth width should be reduced or the lower incisor be restored to balance the Bolton's ratios. What's most important is to choose proper indications. Patients with mandibular dental developmental deficiency need oral rehabilitation to replace missing mandibular incisor and improve profile. Extraction of two maxillary premolars helps to construct favorable intercuspid relationship, and is especially suitable for protrusion cases and with critical aesthetic requirement or anterior teeth crowding [10]. For those patients with good profile, normal overjet, enamel stripping of maxillary approximal surfaces is suggested. Moreover, the interproximal reduction should be carried out with progressively finer strips, to achieve a polished enamel surface to reduce susceptibility to caries. The importance of adequate oral hygiene should be greatly stressed to the patient, even if no higher incidence of caries had been reported after treatment with interproximal reduction [15].

It must be notified that the treatment strategy employed for patients with congenitally missing mandibular incisors must be taken into consideration for all diagnostic criteria, including the patient's profile, skeletal growth pattern, aesthetics requirement and oral hygiene. The Bolton's ratios are useful and provide an effective guidance for orthodontic treatment planning.

## CONCLUSIONS

The measurement of Bolton's ratios in the Chinese orthodontic patients with mandibular congenital missing incisor might be clinically beneficial for optimum treatment outcomes. Guided by the Bolton's ratios, the suggested treatment options for congenitally mandibular incisor missing cases are as follows:

1. If the patients presented with a good profile and normal overjet, stripping of the enamel in the maxillary teeth could achieve good occlusion and normal anterior Bolton's ratios.
2. If the patients presented with mandibular retrusion, replacing the missing incisor prosthetically by opening spaces could be effective to improve the profile.
3. If the patients presented with a convex profile, extraction of one more lower central incisor and two upper first premolars plus reshape of the lower teeth could achieve ideal occlusion and improve profile.

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Received: June 01, 2009 Revised: July 23, 2009 Accepted: July 26, 2009