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## TOOTH SIZE DISCREPANCY IMPORTANCE AS A DIAGNOSTIC TOOL FOR ORTHODONTIC TREATMENT PLANNING: A REVIEW

Ahmad Hajar\*

### Abstract

The main goal in comprehensive orthodontic treatment is to obtain an optimal functional occlusion, overbite and overjet. Tooth size discrepancies of the maxillary and the mandibular arches are an important factor for achieving this goal. Inadequate relationships between the maxillary and the mandibular teeth can pose problems in achieving the ideal occlusion. Early treatment planning and proper diagnosis of tooth size discrepancy minimizes problems attained at finishing stage. Bolton's ratios set an ideal relationship of maxillary tooth width to mandibular tooth width. This article shows the significance, validity as a diagnostic tool and the methods of measuring tooth size discrepancy.

Keywords: Bolton's ratio - tooth size discrepancy – malocclusion – overbite – overjet.

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## IMPORTANCE DE LA VARIABILITÉ DANS LA TAILLE DES DENTS COMME OUTIL DE DIAGNOSTIC POUR LA PLANIFICATION DU TRAITEMENT ORTHODONTIQUE: UNE REVUE DE LA LITTÉRATURE

### Résumé

*Le principal objectif du traitement orthodontique est d'obtenir une occlusion fonctionnelle, un recouvrement et un surplomb optimaux. La différence dans la taille entre dents maxillaires et dents mandibulaires est un facteur important pour la réalisation de cet objectif. Les rapports inter-arcades inadéquats peuvent poser des problèmes dans la réalisation de l'occlusion idéale. La planification du traitement et le diagnostic correct de la différence des dimensions des dents réduisent les problèmes au stade final du traitement. Le rapport de « Bolton » établit une relation idéale entre la largeur des dents maxillaires et celle des dents mandibulaires. Cet article montre l'importance et la validité des méthodes de mesure de la divergence des tailles des dents.*

Mots clés: rapport de Bolton – malocclusion – recouvrement - surplomb.

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## Introduction

Orthodontic diagnosis and treatment planning poses several significant challenges for clinicians with respect to their ability to provide the most predictable results for the patient in an effective, efficient and safe manner. Similarly, orthodontists must address these challenges of assessing treatment results in an objective manner.

Orthodontic treatment goal is to simply place the teeth in proper interdigitation with correct overjet and overbite [1]. Reaching this goal is much more complicated than simply knowing it. Biological limitations make it nearly impossible to attain an ideal outcome without loss or gain of the tooth structure through extractions or composite build-ups.

Inter-arch tooth size discrepancy is the most encountered limitation, which refers to the tooth size proportion of the maxillary teeth to that of mandibular teeth. If the proportions of the maxillary to those of mandibular teeth are not equivalent, it becomes very difficult, if not impossible to align teeth in a correct position [1].

The orthodontic “finishing” phase or detailing of occlusion requires complicated biomechanical forces to reach an ideal orthodontic treatment. Whenever the patient has significant tooth size discrepancy (TSD) between upper and lower arches, orthodontic alignment to attain an ideal occlusion may not be possible. For proper occlusion with normal overjet and overbite, the maxillary to mandibular teeth must be proportional in size [2]. Widely varying opinions exist on the need for the documentation of TSD before starting orthodontic treatment, the frequency of occurrence and the amount of discrepancy that is clinically significant [3].

G.V Black in 1902 [4] was one of the earliest investigators that discussed the topic of the tooth size at the beginning of the twentieth century. A large number of human teeth were measured and tables recording their mean dimensions were constructed.

These tables are considered until now as an important research reference to refer to. Neff [5] defined the “anterior coefficient” in an effort to simplify the determination of the intermaxillary tooth - size relationship. Lundström [6] developed the “anterior index” and determined that the tooth width had a great influence on the alignment of the arches, overbite and overjet.

It can be useful for an orthodontist to determine if there is an inter-arch tooth size discrepancy (ITSD) before treatment begins. This allows the practitioner to develop the treatment plan in a way that will take ITSD into account during the treatment instead of trying to manage it at the end. Several methods have been used to determine ITSD. Of these methods the one most commonly used is the Bolton analysis [1].

The 1958 publication of Bolton's seminal TSD study has long been the gold standard in orthodontics to clinically determine the TSD; Bolton with his analysis became the first person to develop a simple and clinically useful method for measuring TSD. By simplifying the method of measuring tooth size, Bolton aimed to facilitate the treatment planning and the determination of the functional and the esthetic outcomes of orthodontic cases [7].

Bolton [8] recognized the need for a clinically applicable way to determine the influence of the tooth size on disharmonies in occlusion. In Bolton's introduction, he pointed to Ballard [9] and Neff's [5] earlier studies as important work in the examination of TSD. Bolton selected 55 cases, drawn from ten different private practices in the Seattle, Washington area, with excellent occlusion. The mesiodistal dimensions of the teeth from the first molar to the contralateral first molar in the same arch were measured and the sum of the twelve maxillary teeth was totaled and compared to the sum of the twelve mandibular teeth. The same method was used to set up a ratio between the maxillary and the mandibular anterior teeth [8].

Bolton concluded that these 2 ratios should be used as tools for orthodontic diagnosis, allowing the orthodontist to gain insight into aesthetic and functional outcomes of the given case needing to use a diagnostic setup [8].

During the diagnostic phase of treatment, a quick analysis is ensured by the determination of the ratios and means for both the anterior and the overall dentition. By applying this method, the clinician could initially measure the mesiodistal tooth width of the upper and lower teeth and immediately recognize if a discrepancy exists by comparing the anterior and overall ratios to those published by Bolton. Also, it provides the relative size difference which may exist between the upper and the lower arches. Bolton also expanded the clinical application of his analysis. Bolton's standard deviations from the original are used to determine the need for addition of tooth tissue by restorations or reduction of tooth tissue by interdental stripping [10].

### This review aims to:

- Analyze the different methods for measuring the TSD and significance in the final finishing stage of orthodontic treatments.
- Highlight on the prevalence of TSD in different populations.
- Evaluate the TSD and its relationship with the gender, malocclusion and ethnicities.
- Identify the applicability of TSD ratios as a diagnostic tool for treatment planning.

### Significance of measuring TSD

TSD is an overlooked problem in retention [11]. The correct coordination of arches is difficult to reach, without proper mesiodistal tooth size/ratio between mandibular and maxillary teeth [12].

Bennett and McLaughlin [13] added a seventh key into Andrews six keys of normal occlusion which was the correct tooth size. In order to achieve a good occlusion with satisfactory inter-

cuspatation and interdigitation of teeth and a correct overjet and overbite, the maxillary and mandibular teeth must be proportional in size. Sperry et al. [14] found that the harmony in mesio-distal width of maxillary and mandibular teeth is one of the major factors in coordinating posterior intercuspation, overjet and overbite in centric occlusion. The tooth size must be in harmony with the arch size to allow proper alignment [15].

Ballard [9] reported in his study that 90% of the casts of 500 patients examined had a TSD. If maxillary anterior teeth are too large related with the opposing mandibular anterior teeth, clinical manifestations vary from various problems as higher overjet and deep overbite or a combination of both, crowded anterior segment or buccal segment out of proper occlusion. On the other side, if mandibular anterior teeth are too large related to the opposing maxillary teeth, an end to end relationship, spacing in maxillary anterior segment, mandibular crowding in incisors and improper occlusion of posterior teeth may result [10].

#### Validity of Bolton's analysis for TSD as diagnostic tool

Although Bolton's analysis for TSD determination has been considered to be handy and easy to use, its validity and accuracy have been discussed and disputed [16, 17]. Many studies have reported that 20 to 30% of the overall population inherently possess a significant anterior TSD and yet demonstrate an excellent occlusion [3]. One study suggested that in cases with thicker upper anterior teeth, proclined incisors, smaller than normal inter-incisal angles, the Bolton's ratio may not be applicable [10]. Another study carried on typodonts evaluated the effects of an artificially introduced TSD to typodonts with excellent occlusion. The teeth width was altered. The typodonts then were set together in the best occlusal fit possible. The study concluded that a satisfactory occlusion could be attained with a TSD up to twelve millimeters [18]. Other stu-

dies have suggested overjet [10], overbite [8], tip of incisors [19], torque of incisors, inter-incisal angles [10, 19], and finally the tooth thickness [10, 20] as an influential factors in achieving excellent occlusion. Using the diagnostic setups, it has been shown that a decrease or an increase in arch length results from changes in the incisal angles [19]. It's important to mention that one study conducted by Rudolph [20] reported a strong correlation between upper incisal tooth thickness and anterior tooth size ratio. He suggested two formulas for anterior tooth size relations under the circumstances of an ideal anterior proclination.

#### Methods of measuring TSD

Studies have focused on varying aspects of TSD including methods of measurement, prevalence, gender, race, extractions and malocclusion type. Bolton [8] developed a formula to calculate TSD between upper and lower teeth as following:

Overall ratio = (Sum of mesiodistal widths of twelve mandibular teeth) / (Sum of mesiodistal widths of twelve maxillary teeth) x100

Anterior ratio = (Sum of mesiodistal widths of six mandibular teeth) / (Sum of mesiodistal widths of six maxillary teeth) x 100

In order to analyze Bolton's ratios, several methods are available for measuring tooth width, and these are continuing to develop with increasing advances in technology. If a method of measurement is to be widely used, it is important to be quick, easily applicable and reproducible.

The traditional method of measurement used by Bolton [8] and Neff [5] was the needle point divider. The needle point divider can be used intra-orally or on study casts. The divider can be measured directly with a ruler or holes can be punched into graph paper and then measured. Another commonly used instrument is the caliper [21]. There are several types of calipers that could be used to analyze Bolton's

ratio including Boley gauges, dial calipers or digital calipers. Shellhart et al. [21] suggested that Bolton's analysis may be appropriate to be used as a screening tool to determine the possible range of discrepancy because of its ease and rapidity. Although, if the discrepancy range indicates two treatment alternatives, a diagnostic wax up is considered, even though it is more time consuming [21].

Ho and Freer [22] stated that digital calipers are arguably the most popular and simplest type of caliper as a single value is displayed on the screen and could be integrated with computer software. This may reduce any calculation or transfer errors associated with manual methods. In addition, study casts now can be digitized or scanned into a computer so that images can be measured on screen.

With the increase in popularity of digital models, several studies were conducted on the accuracy of measuring TSD of computerized models compared to those of plaster models. Tomassetti et al. [23] were first to compare computerized methods to manual measuring method. Three methods of computerized TSD measurements - Hamilton Arch Tooth System, QuickCeph, and OrthoCad - were compared to the gold standard of manual measurements with vernier calipers. No statistically significant error was found between any of these methods but clinically significant differences (>1.5 mm) were found for each method. Each of the digital measurement methods in the study was faster than the manual method.

Further research found that measurements from digital models are not significantly different than those of plaster models. The digital models were accurate enough and significantly faster to measure, allowing the orthodontist to make the same diagnoses and treatment planning decisions that would have been made with plaster models [24, 25].

A commonly practiced method for measuring TSD is "eyeballing" the models and estimating the TSD. Proffit

[26] suggests an easy way to estimate TSD by comparing the maxillary laterals to those of mandibular laterals in width. If the maxillary laterals appear to have widths which are equal to or less than those of the mandibular laterals then a mandibular excess is likely present. He also stated that the maxillary second premolars should be equal or roughly equal in size. However, Othman and Harradine [27] found that visual estimation is a poor method of measuring TSD as orthodontists who used it missed picking out cases that didn't have significant discrepancies, but still 30% of those cases were guessed incorrectly.

The most accurate and reproducible results for studies measuring TSD were achieved with usage of vernier calipers [21, 28]. Vernier calipers digitally linked to computer programs provided additional accuracy as the error of data recording and transfer is eliminated [22]. This is supported by Zilbermann et al. [29] who found that the measurements made up using digital calipers such as the HATS system, produced the most accurate and reproducible results. This is most probably because investigators can measure more accurately on plaster models as compared to digitized or scanned 3-dimensional models, with less risk of error by inaccurate data recording or analysis. These results suggest that measurements for future studies assessing TSD are best carried out by using digital calipers connected to computerized analysis software.

## Prevalence

The prevalence of a TSD depends on the proportion of occlusions falling outside two standard deviations from Bolton's mean ratios. The 4th edition of Proffit's textbook sets the prevalence at 5% [26]. However lots of studies reported a higher prevalence of TSD with a greater percentage of these patients having anterior TSD than an overall TSD. The table 1 provides a summary of the literature.

Author	Anterior discrepancy	Total discrepancy
Crosby and Alexander [12]	22.9%	–
Freeman et al. [16]	30.6%	13.5%
Santoro et al. [30]	28%	11%
Araujo and Souki [31]	22.7%	–
Bernabé et al. [32]	20.5%	5.4%
Uysal and Sari [33]	21.3%	18%
Paredes et al. [34]	21%	5%
Endo et al. [35]	21.6%	8.3%
Othman and Harradine [27]	17.4%	5.4%
Barbara et al. [36]	31.2%	–
Johe et al. [37]	17%	12%
O'Mahony et al. [38]	37.9%	–
Naseh et al. [39]	28.3%	20%

Table 1: Prevalence of anterior and overall TSD as reported in the literature.

Johe et al. [37] attributed the higher prevalence of TSD in a lot of studies compared to Bolton's study due to the varying ethnic and genetic sample population. Almost all of the studies that examined the prevalence of TSD have concluded that the use of Bolton's analysis prior to orthodontic treatment is recommended and essential in treatment planning, as anywhere from 13-30% of patients can have a clinically significant TSD.

### TSD and malocclusion groups

All studies that have focused on the prevalence of a Bolton's discrepancy in a sample of orthodontic patients have looked up at different Angle's malocclusions with varying results. Studies found up relative mandibular tooth size excess in Class III malocclusions [14, 31, 40 - 43], relative maxillary excess in Class II malocclusions [40], whilst other studies found no significant differences [12, 33, 37, 44].

### TSD and gender

A lot of studies didn't find any significant differences between TSD in males and females [31, 38, 40, 42, 45, 46]. Smith et al. [1] found that posterior and overall ratios were significantly larger in males than females,

although the differences were small (0.9% for the posterior and 0.7% for the overall ratio).

### TSD and ethnic- racial differences

Lavelle [47] compared mesio-distal crown diameters of the maxillary and the mandibular teeth in a total of 120 casts with excellent occlusion from three major racial groups (White, Black and Far-eastern). Percentage of overbite was greater in Caucasoids than Mongoloids and that for Negroids was intermediate. Lavelle found that Blacks had the highest overall and anterior TSD ratios while Whites had the lowest ratios, while people of Eastern Asia descent between the two groups.

Smith et al. [1] support the evidence of racial variation with respect to tooth size; 60 study models, 30 males and 30 females from each racial group Black, Hispanic, and White were measured and anterior, posterior and overall ratios were compared. The authors found that the anterior ratio was similar to Bolton's ratio, while the total ratio was different for all three groups.

Paredes et al. [34] determined the Spanish population values and ratios. Bolton's ratios were significantly different requiring specific standards

for Spanish population. Researchers found also that Bolton's anterior ratio was not applicable to a Japanese population, and that specific Japanese standards were required [35].

Despite of all ethnic and racial differences reported in the literature, other studies coincided with the results of Bolton. Al-Tamimi and Hashim [45], established tooth-size ratios in a Saudi population and realized that Bolton's prediction tables can be used. Also Bolton standards could be used for an Iranian- Azari population [48].

## Conclusion

Tooth size discrepancy plays an important role in the development of an ideal occlusion with proper form, function and esthetics. Having the ability to predict such discrepancies before initiating treatment allows the orthodontist to adjust the treatment plan that provides the most efficient and effective way to help the patient.

The usage of Bolton's analysis for measuring TSD before starting an orthodontic treatment aids in the development of an orthodontic treatment plan and predicts the functional and esthetic outcomes of the case. Tooth size ratios may be influenced by other factors such as upper incisors thickness, anterior incisors inclination, overjet and overbite which should be further investigated.

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