Effects of premolar extractions on Bolton overall ratios and tooth-size discrepancies in a north Indian population

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ABSTRACT

Aim: The purpose of this study was to evaluate the Bolton overall ratio in a north Indian population reporting for orthodontic treatment and to determine the effect of extractions on the Bolton ratios. Another aim of the study was to check the effects of different extraction patterns on the final Bolton ratio.

Materials and Methods: One hundred and twenty pre-treatment dental casts (60 males and 60 females) of orthodontic patients were selected randomly. Mesio-distal dimensions of the mandibular and maxillary teeth were measured before treatment, and subjected to Bolton analysis. Hypothetical tooth extraction by the following combinations: All the first premolars, all the second premolars, upper first and lower second premolars and upper second and lower first premolars were performed for each patient. The measurement results were again subjected to Bolton analysis to see whether any tooth-size discrepancy had been created.

Results and Conclusion: The tooth material ratio of the studied north Indian population shows a mild maxillary tooth material excess. Extraction of premolars in any combination causes the maxillary tooth material to further increase. There is no significant sex difference in the tooth material ratios with or without extractions. In patients requiring extraction; all first premolar extraction or maxillary first and mandibular second premolar extraction should be preferred. For deciding a treatment plan involving extraction of teeth, we need to consider that the maxillary tooth mass may increase after extraction. Furthermore, the normal or the clinically significant tooth size discrepancies may change following extraction of teeth.

Key words: Bolton analysis, extraction pattern, tooth size discrepancy

INTRODUCTION

Finishing of an orthodontic case begins with proper diagnosis. Andrew’s has given six keys of normal occlusion, which according to him are essential for a balanced and stable occlusion.[1] Bolton has further given a seventh key which is as important as Andrew’s keys to attain not only a proper occlusion but also a normal overjet, and overbite of a finished case. The Bolton anterior and overall ratios were defined as the ratios of the mesio-distal widths between the 6 anterior maxillary and mandibular teeth, and the ratios of the mesio-distal widths between the 12 anterior maxillary and mandibular teeth respectively.[2] There is evidence in the orthodontic literature pointing towards sex and ethnic differences in the tooth size ratios. Furthermore, some investigators have reported that following orthodontic extraction there is a change in the Bolton ratios.[3,4]

In cases with space discrepancies, orthodontic treatment usually involves extraction of teeth, specifically the premolars, to attain proper alignment, angulations, and inclinations of teeth. Bolton in 1962 had concluded that extraction of first premolars led to a decrease in the overall tooth ratio.[3] Yang et al. and Li et al. reported similar findings.[6,7] However, Saatci and Yukay in 1997 reported that the overall ratio increased after removal of all first premolars and upper first and lower second premolars.
but decreased after extraction of all second premolars and upper second and lower first premolars. One of the reasons for these variations may be the different populations on which these studies were based. Studies by Basaran et al., Smith et al. and Santoro et al. have shown a difference in the tooth size ratios in different ethnic groups, malocclusions, and sex.

The effect of different extraction patterns on the Bolton ratios would be helpful in not only deciding the final overjet, overbite and occlusion of the patients but also to plan the extraction pattern and the need for inter-proximal reduction. Studies have found that ratios more than 2 SD from Bolton ratio indicate clinically significant overall tooth size discrepancies. For clinical purpose, it is more meaningful to know this significant difference in millimeters and some investigators have selected 1.5 mm as an appropriate limit for clinically significant discrepancy. Proffit and Ackerman have also quoted that any tooth-size discrepancies less than 1.5 mm are rarely significant. Recent studies by Crosby and Alexander in 1989, Othman et al. in 2007 and much more recently Endo et al. in 2009 have given this threshold as 2 mm. For the current study, 2 mm was considered as the threshold for clinical significance.

There is a lack of studies regarding the effect of extraction pattern on the Bolton ratios in the Indian population. Furthermore, the difference in male and female Bolton values needs to be studied. The purpose of this study was to compare the Bolton ratios in males and females in an Indian population and to see the effect of premolar extractions on the Bolton overall ratios in an Indian population.

**MATERIALS AND METHODS**

The study models of 120 Indian subjects were selected retrospectively from the records of patients who had started orthodontic treatment in the department during 2012-13. The study models were of 60 male patients and 60 female patients. The models selected had a full complement of teeth present up to the first permanent molars, and all the teeth were fully erupted. One operator examined the models and concluded that all the teeth were intact without any fractures, class II or class III cavities or restorations or any crowns present. Models having any tooth size or shape anomalies or severe attrition of teeth were also excluded from the study.

Digital caliper (Mitutoyo, Kawasaki, Japan) was used to measure the mesio-distal widths from first molar on one side to the first molar on the other side for both the maxillary and mandibular arches. The tooth material was calculated by measuring the maximum mesio-distal dimensions of the teeth up to the nearest of 0.01 mm on each cast and adding them up separately for the maxillary and the mandibular cast.

The overall Bolton ratios were calculated for all the models, and this was designated as the non-extraction group. Following this four other groups were formed (using the same models) and the Bolton ratios were calculated in them following a hypothetical extraction pattern. In group 2, (designated as 4/4) extractions of all first permanent premolars was planned and they were excluded from the total maxillary and mandibular tooth material. In group 3, (designated as 5/5) all second permanent premolars were excluded from the total tooth material. In group 4 (designated as 4/5) upper first premolars and lower second premolars were excluded and in group 5 (designated as 5/4) upper second premolars and lower first premolars were excluded from the total tooth material calculated.

The values obtained in each group were subjected to statistical analysis to see the effect of extraction pattern on the Bolton ratios.

The values were further subjected to qualitative analysis by classing under three categories i.e., clinically acceptable (up to ± 2.0 mm of tooth material excess in either arch). Maxillary excess (more than 2.0 mm tooth material excess in the maxillary arch and mandibular excess (more than 2.0 mm tooth material excess in the mandibular arch). Following this percentage of samples in each group was calculated.

The values obtained were subjected to analysis of variance (ANOVA) and Bonferroni’s Multiple Comparison Test to determine how many subjects were present in each category if different extractions were planned for them and whether this difference was statistically significant. Statistical differences were determined at the 95% confidence level ($P < 0.05$). Percentage analysis was carried out using the Chi-square test.

**RESULTS**

**Analysis of Error**

Repeated measure method was used to assess the reliability of measurements. A total of 25 models were selected randomly and measured by two different observers to evaluate inter-operator variation. A paired t-test was carried out to assess the reliability of measurements. The $t$ value obtained was 1.43 indicating a $P$ value of 0.154 i.e., there was no statistical difference between the measurements indicating that the measurements obtained were reliable.

In non-extraction group, there was a mild maxillary tooth material excess (0.37 mm) for both males (0.26 mm) and females (0.49 mm). This difference increased to 1.53 mm (1.47 mm in males and 1.59 mm in females) when all first premolars were extracted, 1.63 mm (1.58 mm in males and 1.68 mm in females) when maxillary first and mandibular second premolars were extracted. In cases with all second premolar extraction, the maxillary tooth material excess was 2.07 mm (1.91 mm in males and 2.22 mm in females), and when maxillary second premolars were extracted in combination with the mandibular first premolars a maxillary excess of 2.12 mm (1.96 mm in males and 2.29 mm in females) was found [Table 1].
Table 1 indicates that one-way ANOVA shows a highly significant difference in the amount of maxillary tooth material excess for various extraction patterns in both males and females.

There was a highly significant difference in the tooth material excess before extraction as compared to post-extraction for all the extraction patterns in both males and females.

In the overall sample, the extraction of all first premolars resulted in a significantly lesser maxillary excess as compared to when extracting all second premolars or extracting maxillary second and mandibular first premolars.

There was no significant difference in the tooth material ratios in between the various other extraction patterns for either males or females.

Two-way ANOVA was carried out to compare the effect of extraction pattern and sex on the amount of tooth material excess, and the results indicated a highly significant difference between the various subgroups [Table 2].

Bonferroni comparisons for the same extraction pattern showed no significant difference between the male and the female population [Table 2]; however, there was a difference in the significance levels between different extraction pattern.

Table 3 shows the distribution of subjects into various groups (based on tooth material excess) for each extraction pattern. Chi-square test shows that there was a significant difference in the distribution of subjects for each group when the non-extraction pattern was compared to any of the extraction patterns. This difference was significant in both males and females.

In between the various extraction patterns, there were significant differences in the distribution of subjects for maxillary second premolars and mandibular first premolars with all the other extraction patterns in males. In case of females, there were significant differences between all first premolar extraction with all second premolar extraction and maxillary second premolars with mandibular first premolars. Furthermore, there was a significant difference between maxillary first premolars with mandibular second premolar extraction as compared with all second premolars and maxillary second premolar – mandibular first premolar combination.

It was seen that with extraction of premolars, there was a shift of the population towards maxillary excess group.

**DISCUSSION**

The importance of tooth size discrepancies in orthodontic diagnosis is widely accepted as the relationship between the upper, and lower tooth material is related to orthodontic finishing excellence.
Bolton values before and after the hypothetical premolar extractions in four combinations were calculated in order to assess the incidence of changes and to evaluate their clinical importance. When tooth size discrepancy is more than 1.5 mm it is considered as clinically significant.

Various studies have been carried out to check for the gender differences in the Bolton ratios. We found no gender differences and this was in accordance with previous studies.\(^{3,19,20}\)

Table 2: Two-way ANOVA of tooth material excess as a function of sex and extraction pattern and Bonferroni comparisons within the same extraction patterns

| Extraction pattern | Two-way ANOVA | Bonferroni multiple comparisons between males and females with same extraction pattern |
|--------------------|---------------|-------------------------------------------------------------------------------------|
|                    |               | t value    | P value (NS) |
| Non-extraction     | P<0.0001*     | 2.212      | >0.05        |
| First premolar     |               | 1.214      | >0.05        |
| extraction  4/4     |               |            |              |
| Second premolar    | 2.966         | >0.05      |              |
| extraction  5/5     |               |            |              |
| Maxillary first     | 1.009         | >0.05      |              |
| and mandibular     |               |            |              |
| second premolar     |               |            |              |
| extraction  4/5     |               | 3.225      | >0.05        |
| Maxillary second    |               |            |              |
| and mandibular first premolar extraction 5/4 | | | |
*Significant NS – Not significant; ANOVA – Analysis of variance

In the non-extraction group, the maxillary tooth material was more than that of the mandible with a minor maxillary excess of 0.37 mm. According to the Bolton studies in a normally distributed population only 5% of the subjects would fall beyond 2 SD. Sharma et al.\(^{21}\) in their study on Indian population have found this to be 8%, but they also reported a tooth material excess (>2 mm) in 36% patients. They did not study the effect of extraction pattern on the Bolton values. Our study found 16.4% of the sample had a total tooth material beyond the Bolton 2 SD. These findings are in accordance with studies by Santoro et al. and Freeman et al. who found this to be 11% and 13.5% respectively.\(^{11,14}\) This indicated that there is a greater variation in the tooth sizes of the current population as compared to some of the previous studies.

The effect of extraction pattern on the Bolton ratios is well-recognized, and it was quantified by Bolton himself and much more recently by Tong et al. and Kayalioglu et al.\(^{7,22}\) The current study evaluated the effect of various extraction patterns on the Bolton ratios, and we found that with any extraction pattern, the maxillary tooth material excess increased. This was similar to studies by Endo et al. and Gaidyte and Baubiniene.\(^{3,4}\)

The qualitative analysis also showed similar finding that with any extraction pattern a large population shifted from acceptable tooth material to maxillary excess group. This shift was different for different extraction patterns. Our study shows that in-patients requiring extraction it is better

Table 3: Distribution of subjects into normal, mandibular and maxillary excess with different extraction pattern and their statistical analysis

| Extraction pattern | Clinically acceptable 0±2.0 mm (%) | Maxillary excess >2.0 mm (%) | Mandibular excess >2.0 mm (%) | Chi-square significant comparisons |
|--------------------|------------------------------------|-----------------------------|-------------------------------|----------------------------------|
| Overall n=120      |                                    |                             |                               |                                  |
| Non-extraction     | 104 (86.7)                         | 12 (10)                     | 4 (3.3)                       | Non-extraction versus all extraction patterns *** |
| First premolar     | 82 (68.4)                          | 37 (30.8)                   | 1 (0.8)                       | 4/4 versus 5/5* and 5/4** |
| extraction  4/4     |                                    |                             |                               | 4/5 versus 5/5*and 5/4** |
| Second premolar    | 63 (52.6)                          | 56 (42.6)                   | 1 (0.8)                       |                                  |
| extraction  5/5     |                                    |                             |                               |                                  |
| Maxillary first     | 76 (63.4)                          | 43 (35.8)                   | 1 (0.8)                       |                                  |
| and mandibular     |                                    |                             |                               |                                  |
| second premolar     |                                    |                             |                               |                                  |
| extraction  4/5     | 76 (63.4)                          | 43 (35.8)                   | 1 (0.8)                       |                                  |
| Maxillary second    | 55 (45.8)                          | 65 (54.2)                   | 0 (0)                         |                                  |
| and mandibular first premolar extraction 5/4 | | | |
| Males n=60          |                                    |                             |                               |                                  |
| Non-extraction      | 56 (93.4)                          | 2 (3.3)                     | 2 (3.3)                       | Non-extraction versus all extraction patterns *** |
| First premolar      | 42 (70)                            | 18 (30)                     | 0 (0)                         | 5/4 versus 4/4**, 4/5* and 5/5* |
| extraction  4/4     |                                    |                             |                               |                                  |
| Second premolar     | 36 (60)                            | 24 (40)                     | 0 (0)                         |                                  |
| extraction  5/5     |                                    |                             |                               |                                  |
| Maxillary first and | 37 (61.7)                          | 23 (38.3)                   | 0 (0)                         |                                  |
| mandibular second   |                                    |                             |                               |                                  |
| premolar extraction 4/5 |                                    |                             |                               |                                  |
| Maxillary second and | 31 (51.7)                          | 29 (48.3)                   | 0 (0)                         |                                  |
| mandibular first    |                                    |                             |                               |                                  |
| premolar extraction 5/4 |                                    |                             |                               |                                  |
| Females n=60        |                                    |                             |                               |                                  |
| Non-extraction      | 46 (76.6)                          | 10 (16.7)                   | 4 (6.7)                       | Non-extraction versus all extraction patterns *** |
| First premolar      | 40 (66.7)                          | 19 (31.7)                   | 1 (1.6)                       | 4/4 versus, 5/5**, 5/4** |
| extraction  4/4     |                                    |                             |                               | 4/5 versus, 5/5*, 5/4** |
| Second premolar     | 27 (45)                            | 32 (53.4)                   | 1 (1.6)                       |                                  |
| extraction  5/5     |                                    |                             |                               |                                  |
| Maxillary first and | 39 (65)                            | 20 (33.4)                   | 1 (1.6)                       |                                  |
| mandibular second   |                                    |                             |                               |                                  |
| premolar extraction 4/5 |                                    |                             |                               |                                  |
| Maxillary second and | 24 (40)                            | 36 (60)                     | 0 (0)                         |                                  |
| mandibular first    |                                    |                             |                               |                                  |
| premolar extraction 5/4 |                                    |                             |                               |                                  |

***Highly significant; **Very significant; *Significant NS – Not significant
to extract all first premolars or maxillary first and mandibular second premolars.

In cases where all second premolar extractions were carried out or maxillary second premolars were extracted in conjunction with the mandibular first premolars there is a tendency for a large maxillary excess.

Clinically, these findings indicate that in our population extraction of all first premolars or maxillary first and mandibular second premolars has a lower chance of creating Bolton discrepancy though the values need to be evaluated from case-to-case.

**CONCLUSION**

The results of our study indicate that

- Generally the tooth material ratio of north Indian population shows a mild maxillary tooth material excess
- Extraction of premolars in any combination causes the maxillary tooth material to further increase
- There is no significant sex difference in the tooth material ratios with or without extractions
- Non-extraction cases have a generally better Bolton’s ratio as compared to extraction patients
- In patients requiring extraction all first premolars or maxillary first and mandibular second premolar extraction should be preferred.

For deciding a treatment plan involving extraction of teeth, we need to consider that the maxillary tooth material may increase after extraction. Furthermore, the normal or the clinically significant tooth size discrepancies may alter following the extraction of teeth.

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**How to cite this article:** Kumar P, Singh V, Kumar P, Sharma P, Sharma R. Effects of premolar extractions on Bolton overall ratios and tooth-size discrepancies in a north Indian population. J Orthodont Sci 2013;2:23-7.

**Source of Support:** Nil, **Conflict of Interest:** None declared.