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Analysis of Bolton Ratios in Skeletal Class I Malocclusion and Effects of Various Four-Premolar Extraction Combinations Before and After Treatment

Abstract: *This study was conducted to find whether different premolar extraction patterns lead to a change in the Overall Bolton ratio from 0.91 and the Posterior Bolton ratio from 1.05, among the Pakistani population in a skeletal class I malocclusion. This quasi-experimental study took place in Khyber College Of Dentistry, Peshawar. Dental plaster models of the patients with skeletal class I malocclusion were collected. A Digital Vernier Caliper was used to calculate the Bolton's ratios. The Bolton ratios were again calculated after hypothetical extractions of all the 1st premolars (4/4), all 5s, upper 4s and lower 5s, and upper 5s and lower 4s. The sample consisted of 12 males and 18 females. The change in Overall Bolton ratios was statistically significant for 4s extractions. For the Posterior Bolton ratio, the 4/4 and 4/5 extraction patterns were significant. Taking out the premolar teeth leads to a statistically significant but clinically insignificant reduction in the Posterior and Overall Bolton ratios in Skeletal class I malocclusion.*

Key Words: Bolton Ratios, 1st Premolar Extractions, 5s Extractions

Introduction

The aim of orthodontic treatment is to achieve a beautiful smile and a good bite. It is not as simple as it looks. Among many requirements, this demands good interdigitation of the teeth – that is, the teeth should fit perfectly when a person bites (Andrews 1972) (Azeem 2017). Wayne A. Bolton, in his study on tooth size ratios and interdigitation of the teeth, found that a good inter-arch relationship is achieved when the ratio of the lower teeth to the upper teeth is 0.91 (91.3 1.91%). Similarly, for the anterior 6 teeth (canines and incisors), a ratio of 0.77 was found to achieve the best alignment of the teeth. (Bolton 1958) from his study, a ratio was also calculated for the posterior teeth (premolars and molars), which came out to be 1.05. These ratios are called Bolton Ratios and any deviation from the ideal ratio is termed as a "Bolton Discrepancy." Bolton discrepancies lead to compromised inter-arch relationships, or to gaps or irregularities between the teeth. Bolton 1962 A skeletal class I malocclusion exists when the upper and lower jaw are in harmony with each other, but the teeth fail to fit due to different etiological factors. It

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amounts to 65% of malocclusions in the Pakistani population. (Ellaithy 2017) Extracting 4 premolar teeth during orthodontic treatment to correct the alignment of the teeth is a norm for orthodontic patients. Holton 2023 This can lead to better stability of the results, Jackson 2017 but whether or not this disrupts the Bolton ratio, leading to compromised inter-arch relationships or to spaces appearing between the teeth, is disputed.

A well-designed study By Mongillo et al. showed that premolar extractions in patients with ideal pre-extraction Bolton ratios lead to a tooth size discrepancy that caused space to appear among the teeth in the lower jaw. Kayalioglu 2005 A detailed study by Ellaithy and Gomaa concluded that among those with ideal Bolton Ratios before any treatment, extractions of 4 premolars lead to a significant discrepancy in the pre-and post-extraction Bolton Ratios. Kumar 2013 A Pakistani study found that premolar extractions in skeletal class II malocclusion (when the upper jaw is larger or the lower jaw is smaller than normal size) lead to a decrease in the Bolton ratios when all 4s or upper 4s and lower 5s were extracted. Machado 2020.

This study was conducted to find whether different premolar extraction patterns (Upper 4: lower 4, upper4: lower 5, upper 5: lower 4, upper 5: lower 5) lead to a change in the Overall Bolton ratio from 0.91 and Posterior Bolton ratio from 1.05, among the Pakistani population in a skeletal class I malocclusion.

The null hypothesis is that there is no difference in the Overall and Posterior Bolton ratios before and after the different premolar extraction patterns.

Material and Methods

Ethical approval was taken from the Research Review Board (52/ADR/KCD) in August 2023 to conduct this quasi-experimental study. It spanned from August to December 2023 in the Orthodontics Department of Khyber College of Dentistry, Peshawar. OpenEpi was used to calculate the sample size. The change in the overall Bolton Ratio (%) was taken as a parameter. The changes in the ratio of 91.75 0.97 % before extractions and 89.97 0.97 % after extraction lead to a sample size of 14 (7 in each group), keeping a 95% confidence interval and power 90. To assume the normality of data, a sample of 30 patients was taken. Consecutive sampling was used to employ patients who had a skeletal class I base (A-Point-Nasion-B-Point angle (∠ANB) between 2° - 4°). For those patients who were excluded who had had previous orthodontic treatment, any missing tooth from the left 1st molar to the right 1st molar, chipped/worn/decayed teeth, interproximal restorations, or teeth covered by crowns, as all these factors will lead to incorrect calculation of the Bolton ratio.

Dental plaster models of the patients were collected. It was ensured that the dental models did not have any bubbles, voids, or broken plaster. These were used for calculating the Bolton Ratio with a Digital Vernier Caliper (POWERFIX Profi+, Model No: HG00962A) with a least count of 0.01mm. The mesiodistal width of each tooth from the right to left 1st molar in both jaws was measured. The calliper beaks were inserted from the facial aspect perpendicular to the tooth's long axis. The Overall and Posterior Bolton ratios were calculated using the method given by Bolton in his paper:

Overall ratio: Sum of mesiodistal widths of lower teeth from left to right 1st molar/ Sum of mesiodistal widths of upper teeth from left to right molar Posterior ratio: Sum of mesiodistal widths of lower teeth from left 1st molar to left 1st premolar and right first molar to right 1st premolar/ Sum of mesiodistal widths of upper teeth from left 1st molar to left 1st premolar and right 1st molar to right 1st premolar. The ratio was noted down in the datasheet. This was followed by hypothetical extractions of all the 1st premolars (4/4), and the Bolton ratio was again calculated for this scenario by omitting the values of the teeth that had been hypothetically extracted.

The same was done for scenarios for hypothetical extractions of all 5s, upper 4s and lower 5s, and upper 5s and lower 4s.

The measurements were made by 3 researchers. Their intraclass correlation coefficient score was found to be 0.98, which is considered excellent.

SPSS 25 was used for data analysis. Shapiro-Wilk test was used to check for the normality of data. Gender is presented as frequency and percentage. Age and Bolton ratios (Overall and Posterior ratios) are presented as mean and standard deviation (SD). Dependent-sample t-test was used to find the change in Bolton ratios following the different premolar extraction patterns. The alpha value was 0.05.

Results

The sample consisted of 12 males and 18 females, with a mean age of 19.05 4.76 years.

Data was normally distributed (p-value of 0.172 and 0.529 for overall Bolton ratio and posterior Bolton ratio, respectively).

The mean Overall and Posterior Bolton ratios before extraction of the premolars were 0.91 0.01 and 1.05 0.3 respectively, which is clinically insignificant. Following all four extraction patterns, the Overall Bolton ratio was reduced. The change in Overall Bolton ratios was statistically significant, with a p-value < 0.000. (Table 1) For the Posterior Bolton ratio, the 4/4 and 4/5 extraction patterns were significant, with a p-value < 0.000. (Table 2). The ratio increased.

Table 1

Overall Bolton ratios following the four Extraction Patterns

Extraction Pattern of Premolars	Mean and SD following extraction	The mean difference in Bolton ratio Before vs After Extraction	95% CI limits		Test statistic	P value
			Lower	Upper		
4/4	0.89 0.01	0.15 0.01	0.001	0.012	11.33	.000
4/5	0.90 0.02	0.01 0.01	0.002	0.005	4.67	.000
5/4	0.89 0.02	0.03 0.01	0.002	0.021	12.99	.000
5/5	0.89 0.02	0.02 0.01	0.002	0.016	11.09	.000

Table 2

Posterior Bolton ratios following the four Extraction Patterns

Extraction Pattern of Premolars	Mean and SD following extraction	The mean difference in Bolton ratio Before vs After Extraction	95% CI limits		Test statistic	P value
			Lower	Upper		
4/4	1.07 0.04	-0.02 0.02	-.026	-.013	-5.72	.000
4/5	1.08 0.04	-0.03 0.02	-.042	-.0247	-7.47	.000
5/4	1.04 0.04	0.01 0.03	-.001	.019	1.72	.095
5/5	1.05 0.04	-0.004 0.02	-.013	.003	-1.23	.228

Thus, the null hypothesis is rejected: there is a difference in the Overall and Posterior Bolton ratios following extractions of 4 premolars.

Discussion

The significance of the Bolton ratio is well-known to orthodontists and vastly discussed in literature. Mongillo 2021 Najjar 2023 It is this factor that decides whether cutting a tooth to reduce its size is needed, or whether a tooth needs to be filled up to increase its size to achieve proper tooth contacts. It also helps to find out which tooth is at fault when the teeth fail to align during orthodontic treatment.

Orthodontists strive to achieve a proper bite when treating patients, as it is considered to give the most stable results. Othman 2006 The overall Bolton ratio of 0.913 (91.3%), anterior Bolton ratio of 0.772 (77.2%), and posterior Bolton ratio of 1.053 (105.3%) are the set ideals for achieving proper interdigitation of the teeth.

Figure 1

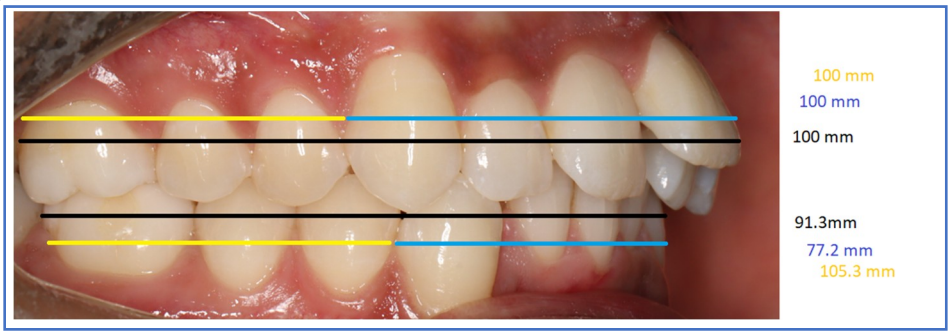

Figure 1: For easier understanding, assume that the total widths (Black line) of the upper 12 teeth add up to 100 mm (100%). For a good fit of the teeth, the sum of the lower teeth must be 91.3 mm (91.3% of the width of the upper teeth). Similarly, if the widths of the upper anterior 6 and upper posterior 3 teeth are 100 mm (100%), then lower anterior teeth must be 77.2 mm (77.2% the width of the upper anterior teeth), and lower posteriors must be 105.3 mm (105.27% the width of the upper anterior) for proper interdigitation.

Proper interdigitation is achieved when the tips of the upper canines and premolars fit in the embrasures of the lower teeth. Disruptions in the Bolton ratio will lead to either the molars or the canine's tip moving forward or backward from its best-fit and most stable position. If the molar's and canine's tip fits into its best-fit position, gaps or irregularities will appear among the teeth if the orthodontist does not take compensatory action.

Figure 2

Figure 2: Demonstration of a disruption in the Bolton ratio when 1st premolars are taken out. As the canine and molar tips fit nicely into the embrasures, space appears in front of the premolar due to its smaller-than-normal size – a Bolton discrepancy. The premolar's size must be increased to close down this space.

In the study by Mongillo et al., the mean overall & posterior Bolton ratios were 91.75 0.97%, & 105.77% 1.99 (n=55), which is similar to our study and the original Bolton study. Following 1st premolar extractions by omitting the widths of premolars from the formula, the percentage changed to 89.97 0.97% & 107.29 2.23%, a change of 1.78 0.50% & 1.52 1.15%, which was statistically significant (< .001). The authors then digitized their study models and virtually extracted all the 1st premolars and calculated the Bolton discrepancy on this digitized set-up to find a new percentage of 91.33 1.32% & 110.48 3.12%. There was a discrepancy of 1.36 1.09 & 3.18 2.59% between the mathematical and digital observations, which was also significantly different ($p < .001$).

The study by Ellaithy and Gomaa (n=220) concluded that all patterns of premolar extractions significantly decreased the overall Bolton's ratio. The mean Overall ratio in Class I patients was 91.77 2.01. Following 4/4 extraction, it decreased to 90.53 2.48. For 5/5 extractions, it reduced to 89.92 2.26. For 4/5 extraction, it reduced to 90.90 2.47, and for 5/4, it reduced to 89.55 2.29. ($p <.001$)

Kayalioglu et al. (n=53) selected models of patients who had undergone all 4 extractions, and who achieved an ideal bite and good esthetics at the end of treatment. The patients had a mean overall Bolton ratio of 90.61 1.08 at the beginning of the treatment. Following extractions of 4/4, it reduced to 0.89 0.01, which was statistically significantly different from the Bolton study (p< .001). They concluded that the ideal ratio in 1st premolar extraction cases should be 0.89, which is the lower range given by Bolton for ideal occlusion. Proffit 1993.

Thus, it can be concluded that following extractions of

premolars, the Bolton ratio is disrupted, which means that the teeth fail to fit properly. In all the studies, including ours, the Bolton ratio reduced, indicating that taking out the premolar teeth leads to a relative reduction in the total size of the lower teeth. This can manifest as gaps appearing between the lower teeth, or irregularity in the upper teeth.

These ratios can be converted into millimetres. In the study by Mongillo et al.[8] (n=55), after digitally extracting 4s and setting posterior teeth into a perfect bite, an average of 1.11 0.92 mm gap appeared between the lower posterior teeth.

Kumar et al. (n=120) found that if a patient already had a Bolton discrepancy before any teeth were taken out, the discrepancy increased following extractions. The discrepancy increased to 1.53 mm when 4/4 were extracted, and 1.63 mm in 4/5 extraction. In 5/5, the upper tooth material excess was 2.07 mm and in 5/4 a maxillary excess of 2.12 mm was found. Turtinen 2021.

It is accepted that a tooth size discrepancy of less than 1.5 mm is seldom significant, and larger discrepancies create treatment problems. Wadood 2023 In our study, mean Overall and Posterior Bolton ratios were 0.99mm and 0.39mm before extraction. These values increased following extraction of the premolars, but none increased to more than 1.5mm. Thus, despite the change in Bolton ratios being statistically significant, it remains clinically insignificant in the Pakistani population. It can be concluded that extractions of upper and lower premolars in all 4 combinations are a safe modality for correction of irregular teeth, with mostly no need to cut down the size of teeth or to fill them up to increase their size for proper interdigitation.

Conclusion

Taking out the premolar teeth leads to a statistically significant but clinically insignificant reduction in the Posterior and Overall Bolton ratios in Skeletal class I malocclusion.

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