Original Article

Outcome of premolar extractions on Bolton's overall ratio and tooth size discrepancies in South India

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Abstract

Aims and Objectives: Attainment of ideal occlusion is often restricted by disproportionate sizes of individual teeth, which is otherwise termed as tooth size discrepancy (TSD). While extraction of teeth for orthodontic purposes is not uncommon, there is considerable resistance against this school of thought. The extraction of premolars, in particular, received considerable attention because of the potential TSD that could result following the extraction of premolars. The aim of the present study was to identify the consequence of premolar extractions on Bolton's overall ratios in South Indian population. **Materials and Methods:** One hundred participants were recruited into the study through purposive nonproportionate quota sampling. Pretreatment dental casts of the study participants were measured for mesiodistal tooth widths to determine Bolton's overall ratio before the hypothetical tooth extractions were performed. The hypothetical extractions were executed in four different combinations as follows: (a) Maxillary and mandibular first premolars, (b) maxillary first premolars and mandibular second premolars, (c) maxillary second premolars and mandibular first premolars, and (d) maxillary and mandibular second premolars. Bolton's overall ratios were calculated after the hypothetical tooth extractions were performed. Statistical analysis was done using the Statistical Package for the Social Sciences, version 20 software. **Results:** It was observed that extractions performed in any of the combinations followed in this study resulted in a decrease of overall Bolton's ratios. However, the discrepancy in tooth size was highest with the extraction of all first premolars, whereas least discrepancy was recorded with all second premolars extraction. It was also found that, based on the combination of teeth chosen for extraction, there was significant difference in Bolton's overall ratios between males and females. **Conclusion:** In formulating a treatment plan involving premolar extraction, significant tooth size discrepancies could change mutually after extraction.

Key words: *Bolton analysis, extraction pattern, malocclusion, premolars, tooth size discrepancy*

INTRODUCTION

Malocclusion can be described as a pronounced deflection from what is conventionally considered a normal occlusion because of skeletal, soft tissue, and local dental factors.[1] Some of the prime determinants of malocclusion are size of the jaw bones; factors influencing the relative positions of the skeletal bases, the arch form; size and structural form of individual teeth; number of teeth present; and morphology and behavior of the soft tissues.

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The six keys to occlusion were first demonstrated by Andrews in 1972 in his study involving nonorthodontic patients. Correct size of the tooth was later added by McLaughlin *et al*.[2] as the seventh key. Black (1902)[3] examined a large number of teeth to establish the normal ranges for size of each tooth in human dentition. Abnormal deviations outside this normal range are caused by developmental disturbances resulting in tooth size discrepancy (TSD).

In 1949, Neff[4] developed the *anterior coefficient*, a ratio of 1.20 to 1.22 by which an ideal overlap of 20% of the lower incisor crown height could be achieved. Ballard[5] and Steadman[6] also made significant combinations to this field, however, Bolton's work[7] was the most recognized. Bolton calculated the ratio of summed mesiodistal widths of 12 mandibular teeth to 12 maxillary teeth, which was termed as Bolton's overall ratio. He had also calculated the anterior ratio by comparing summed mesiodistal widths of 6 mandibular anterior teeth to that of 6 maxillary anterior teeth. For this purpose, Bolton recruited 55 female participants with excellent occlusions. He demonstrated that an overall ratio of 91.3 and anterior ratio of 77.2 were required for optimum intercuspation of maxillary and mandibular teeth. The aforementioned ratios could serve as diagnostic tools, providing clinicians with a scope to estimate the functional and esthetic outcome of treatment without diagnostic workup.[8]

Bolton's research[7,8] had a pronounced influence, and a majority of studies relating to tooth size used his analysis of discrepancy to diagnose TSD. Despite increasing use of Bolton's overall ratio and anterior ratios, the method has certain shortcomings. This method ignores the influence of overbite, overjet, interincisal angle, tip, and thickness of incisors on the relationship between individual teeth. Furthermore, the analysis cannot be used in extraction treatment as the ratio between arches of dissimilar lengths is bound to change, almost always, with extraction of premolars of approximately equal size in both the arches. Bolton's overall ratio should not be used for determining occlusion after removal of 4 premolars.[8]

It is a strongly held opinion by many researchers that TSD can be a direct consequence of premolar extractions. Bolton observed a change in the overall ratio from 91.3 ± 1.91 to 88 ± 1 with extraction of 4 premolars. Saatci and Yukay,[9] Tong *et al*.,[10] and Gaidyte and Baubiniene[11] stated that overall Bolton's ratios were reduced after premolar extraction regardless of the combination observed. It was also identified after premolar extractions that normal and large overall ratios were modified as small and normal overall ratios, respectively. These changes were more pronounced with extraction of all second premolars and with the combination of maxillary second and mandibular first premolars. While the extraction of all second premolars resulted in the least TSD, it was observed that the extraction of all first premolars produced the highest TSD.[12] Literature shows that insufficient tooth size and arch length discrepancy and its applicability as Bolton's discrepancy has racial as well as ethnic variation.[11,13-15] Recently, researchers have also focused on other variables influencing satisfactory occlusal relationships such as arch form, maxillary incisor thickness, and incisor inclinations.[16] Clinically significant TSD can be anticipated in extraction cases as a result of the extraction pattern chosen if due importance was not given to tooth size. The aim of the present study was to identify the consequence of premolar extractions on Bolton's overall ratios in South Indian population and to compare these effects between males and females.

MATERIALS AND METHODS

A total of 100 participants consisting of 50 males and 50 females with less than 3 mm of crowding were selected. The sampling technique used was purposive nonproportional quota sampling. The sample size used in this study is commensurate with the previously published research with regard to the topic under investigation.[9,17,18] Maxillary and mandibular impressions were made and poured in type III dental stone. A digital Vernier caliper (Aerospace) with least count of 0.01 mm was used to measure the mesiodistal width of teeth [Figures 1 and 2]. The study protocol was approved by the institutional ethics committee. All the participants signed an informed consent to participate in the study. No changes were made either in the protocol or in the eligibility criteria after the commencement of the study. The study was conducted between August 2014 and September 2015.

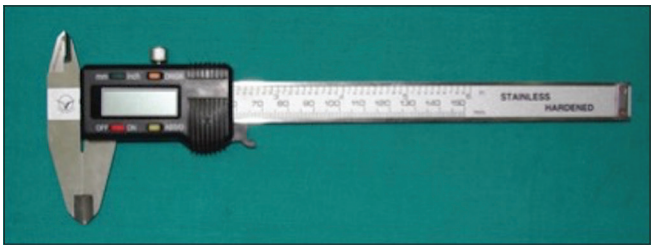


Figure 1: A digital Vernier caliper

Inclusion criteria

- South Indian ethnicity
- No previous orthodontic treatment
- Complete eruption to occlusion of all permanent teeth to first molars
- Class I molar and canine relation, overjet and overbite of 2–3 mm
- Age 12–25 years.

Exclusion criteria

- Crowding more than 3 mm in either of the arches
- Proximal restorations, crowns, and onlays
- Anomalies or mutilated dentitions
- Congenital defects, deformed teeth
- Dentition with attrited teeth below the contact point.

To eliminate the bias that could arise due to interexaminer variability in measurement, all the measurements were recorded by a single investigator. In the literature, two basic instruments that were used for measuring the mesiodistal tooth width include the digital read out sliding calipers with a Vernier scale and a set of engineer dividers used along with a millimeter rule. In the current study, all the teeth were measured at the largest mesiodistal crown diameter (to the nearest 0.1 mm), as described by Moorrees and Reed[19], from the right 1st molar to left molar in the upper and lower arches with the help of a sliding Vernier caliper to obtain accurate measurements. The caliper beaks were inserted perpendicular to the tooth's long axis from its facial aspect.

Pretreatment dental casts of the study participants were measured for mesiodistal tooth widths to determine Bolton's overall ratio before the hypothetical tooth extractions were performed. The hypothetical extractions were executed in four different combinations as follows: (a) Maxillary and mandibular first premolars, (b) maxillary first premolars and mandibular second premolars, (c) maxillary second premolars and mandibular first premolars, and (d) maxillary and mandibular second premolars. Bolton's overall ratios were calculated after the hypothetical tooth extractions were performed.

Figure 2: Digital Vernier caliper to measure the mesiodistal width of teeth

Mesiodistal error method

To assess measurement error, reproducibility of the investigator was assessed by repeating the measurements after a period of 15 days, as suggested by Dahlberg.[20] Differences in means between the two observations, standard errors associated with a single recording, and the percentage of variance as a result of measurement error were determined for each variable. Method error was determined as suggested by Houston.[21]

Statistical analysis

The data obtained were subjected to statistical analysis using the Statistical Package for the Social Sciences (SPSS), version 20 software (IBM Corp. IBM SPSS Statistics for Windows, Armonk, NY: IBM Corp; 2011). Unpaired *t*-test and one-way analysis of variance (ANOVA) test were employed. The statistical data were summarized in table form.

RESULTS

The results were analyzed using SPSS. One sample *t*-test was used to compare the Bolton's mean after the extraction combination. Males, females, and total participants have been evaluated separately [Table 1]. The mean overall ratio for males was found to be 91.74 ± 2.68,

Table 1: *t*-test extraction pattern comparison

	N	Mean	SD	SE Mean
M_U4L4	50	89.7500	2.67217	0.37790
M_U5L5	50	88.4200	2.02525	0.28641
M_U4L5	50	89.0820	1.91745	0.27117
M_U5L4	50	89.0320	2.01103	0.28440
F_U4L4	50	89.9600	1.67624	0.23706
F_U5L5	50	88.3560	1.88638	0.26677
F_U4L5	50	89.2640	1.85227	0.26195
F_U5L4	50	89.2300	1.94435	0.27497
U4L4	100	89.8550	2.22172	0.22217
U5L5	100	88.3880	1.94740	0.19474
U4L5	100	89.1730	1.87783	0.18778
U5L4	100	89.1310	1.97047	0.19705

SD=Standard deviation, SE=Standard error

in females the overall ratio was 92.07 ± 2.13. The mean overall ratio, regardless of gender was 91.90 ± 2.56. It was observed that in males with the extraction combination of U5L5 obtained a normal Bolton's mean with a value of 88.42% and also the combination of U5L4 just fits in the series with a value of 89.03%.

In females the extraction combination of U5L5 gave a normal Bolton's mean with a value of 88.35% and also the combination of U4L5 just fits in the series with a value of 89.26%. In all the participants the extraction combination of U5L5 resulted in a normal Bolton's mean with a value of 88.38%. In addition, the combination of U4L5 and U5L4 just fits in the normal mean values with values of 89.17 and 89.13%. respectively [Table 1 and Graph 1]. The results of *t*-tests used for testing the significance of various extraction methods to the standard value are summarized in Table 2. The corresponding *P* value suggests the type of extraction protocol for the normal range of Bolton. With the test value kept at 88.0, no significant differences were observed with U5L5 in both males and females as well as in the overall sample regardless of gender ($P = 0.149$, 0.188, and 0.049, respectively). All the other combinations of extraction yielded significant differences in both genders and in the overall sample. Hence, our research concluded that the U5L5 is the only extraction method, which is more effective to achieve Bolton's mean. The four extraction combinations were compared by one-way ANOVA to test the hypothesis that the four extraction patterns are equal [Table 3]. On comparison, it was observed that the significance level is 0.000, which rejects our hypothesis and shows that the four extraction patterns are different.

The variation in the Bolton's overall ratio in the various extraction patterns shows the difference between males and females. In both males and females, upper and lower second premolar extraction groups achieve a normal ratio after extraction. In addition, in males, upper second premolar and lower first premolar extraction group lies in the normal range, whereas in females, the group extracting upper first and lower second premolar group achieve abnormal ratio [Graph 2].

Table 2: *t*-tests used for testing the significance of various extraction methods to the standard value

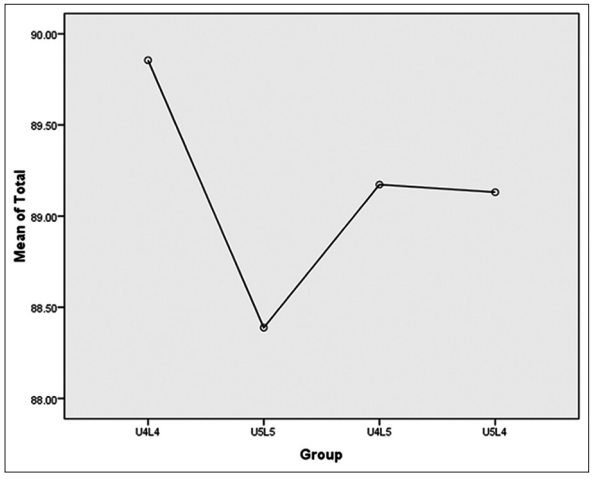
	Test value=88				
	t	df	*P* (two-tailed)	Mean difference	Significant
M_U4L4	4.631	49	0.000	1.75000	Significant
M_U5L5	1.466	49	0.149	0.42000	Not Significant
M_U4L5	3.990	49	0.000	1.08200	Significant
M_U5L4	3.629	49	0.001	1.03200	Significant
F_U4L4	8.268	49	0.000	1.96000	Significant
F_U5L5	1.334	49	0.188	0.35600	Not Significant
F_U4L5	4.825	49	0.000	1.26400	Significant
F_U5L4	4.473	49	0.000	1.23000	Significant
U4L4	8.349	99	0.000	1.85500	Significant
U5L5	1.992	99	0.049	0.38800	Not Significant
U4L5	6.247	99	0.000	1.17300	Significant
U5L4	5.740	99	0.000	1.13100	Significant

Df=Degree of freedom

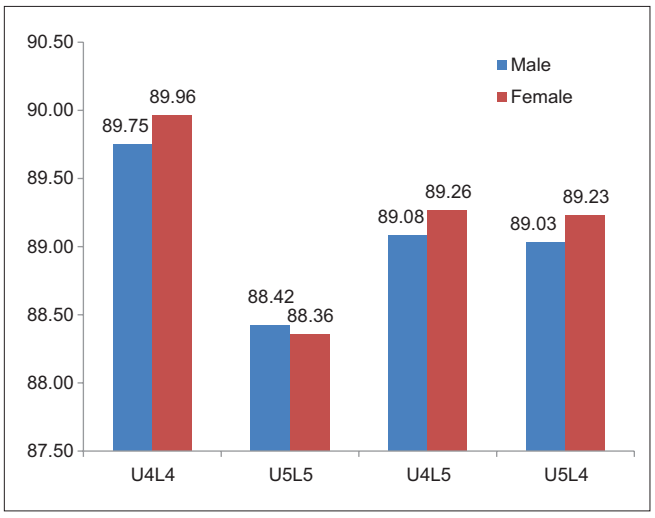
Table 3: One-way analysis of variance comparing the four extraction patterns

Total	Sum of Squares	df	Mean square	*F*	*P*
Between Groups	107.786	3	35.929	8.906	0.000
Within Groups	1597.604	396	4.034		
Total	1705.390	399			

Df=Degree of freedom



Graph 1: Comparison of extraction pattern



Graph 2: Bolton's overall ratio in the various extraction patterns for males and females

DISCUSSION

In our study, significant difference between pretreatment and posttreatment Bolton's values was observed, indicating that the premolar extractions will have a definite effect on the final occlusion. One-way ANOVA showed significant change in the overall ratios from pre-extraction to post-extraction. Our results showed that any combination of premolar extractions resulted in a decrease in the overall ratio, as confirmed by Tong *et al*.[10] However, the study by Heusdens[22] indicated that extraction therapy minimally affected the occlusion; only severe pretreatment Bolton's values will be affected and not the mild ones.

Saatci[9] concluded that the difference between the pretreatment Bolton value and post-extraction Bolton value was significant only for the extraction of all first premolars and insignificant for the other three combinations of extraction. In this study, mean value before extraction was 0.885 and the extraction of all first premolars created more severe discrepancy as the values were increased to 1.252. Conversely, the extraction pattern involving extraction of second premolars in both the arches reduced the discrepancies that existed prior to extraction (0.840). The results of the present study coincides with the aforementioned study conducted by Saatci[9] with mean Bolton's values before extraction being 1.328, which increased to 1.855 after extraction of first premolars, and markedly decreased in value after extraction of second premolars (0.388).

Endo[23] concluded that the Bolton's overall ratio (91.0 + 2.20) decreased after extraction of second premolars (88.89 + 2.11) as well as in maxillary second and mandibular first premolars (88.61 + 2.24) extraction combination. The results of the present study were found to be concordant with that of the study done Endo,[23] where the overall ratio (91.90 + 2.56) decreased after extraction of maxillary and mandibular second premolars (88.38 + 1.94), maxillary second and mandibular first premolar (89.17 + 1.87), as well as in maxillary first and mandibular second premolar (89.13 + 1.97) extraction combinations. Gaidyte[11] stated that extraction of 4 second premolars caused the least TSD changes.

The study conducted by Piyush[24] evaluated the effect of various extraction patterns on the Bolton ratios, and the results obtained were contradictory with those obtained in the current study. His study showed that, in patients requiring extraction, it is better to extract all first premolars or maxillary first and mandibular second premolars. The mean difference before extraction (0.370) was increased (2.070) in all second premolar extraction and decreased in maxillary and mandibular first premolar extraction (1.53) as well as in maxillary first and mandibular second premolar extraction (1.63) combination.

The results of the present study were in accordance with the results of a study conducted by Tong *et al*.[10] stating that both in males and females the overall ratios decreased after extraction of any combination of premolars. In males, statistically significant changes occurred between the overall ratio before extraction (91.74), and after extraction of the first premolars (89.75), whereas no significant changes were observed in maxillary and mandibular second premolar (88.42), maxillary second and mandibular first premolar (89.03) extraction combinations. Whereas in females, the overall ratio before extraction (92.07) decreased after extraction of any combination of premolars, however, statistical significant changes were found with extraction of upper and lowers first premolars (89.96). No significant changes were found with extraction of both maxillary and mandibular second premolars (88.35).

Jarrah[25] quanted Beggs philosophy as strong evidence in support of simulation of Mother Nature. Because second premolars are the teeth that are most commonly missing congenitally, their removal is in accordance with nature. Moreover, as canines are the only teeth left for tearing the food after first premolar extraction, they should be spared and second premolars preferred from even a functional point of view.

However, the present study shows that, in our population groups, extracting upper first premolar and lower second premolar and upper second premolar and lower first premolar also achieved normal ratio. The mean differences with the test value were found to be 0.98 and 0.99, respectively. On statistical evaluation, however, both the groups showed a very weak significance. Thus, these groups are not very reliable to achieve ideal occlusion after extraction in such patterns.

The age group of the participants in this study was deliberately chosen to be between 12 and 25 years. The reason behind the choice could be seen in the less mutilation and less attrition in early adulthood dentition in most of the participants. Thus, the effect of these factors on mesiodistal tooth width could be avoided. This was done in accordance with the studies by Doris *et al*.[26] and Puri *et al*.[27] who acknowledged that early permanent dentition qualifies to be the best sample for measurement of tooth sizes.

None of the previous studies[12,20,21] showed any difference in the extraction patterns among male and female extraction groups. However, the present study showed a difference in the extraction pattern that should be employed in males and females. In males, along with upper and lower second premolars, upper second and lower first premolar also achieve a normal occlusion (89.03). However, in females, upper and lower second premolars and upper first and lower second premolar combination (89.23) should be the choice of extraction to lead to a satisfactory occlusion. This study also highlights the importance of thorough tooth size evaluation in cases that would require extraction for orthodontic reasons, especially with the nonextraction protocol, the other school of thought, resulting in better occlusal contacts and relationships[28] and being increasingly practiced.[29]

Limitations

- The application of this method requires mathematical calculations and use of tables, which sometimes may not be accurate and reliable
- Bolton tooth size ratio would be much better with three-dimensional dental casts than with plaster casts and more accurate with three-dimensional scanning software (50 μ) than using conventional digital caliper gauge (0.01 mm)
- The clinical relevance is limited to local population and cannot be taken as the gold standard to other populations, extraction criteria for the patients should not be dependent on model analysis, but should also consider clinical and cephalometric diagnosis.

Based on these limitations, the authors suggest that future research in this regard should aim at recruiting a large sample from diverse backgrounds, make best use of the advancing technology in the form of three-dimensional dental casts and three-dimensional scanning software (50 μ),[30] and placing specific emphasis on posterior Bolton's ratio because elucidation of overall ratio is often considered debatable.[31] Future studies may also focus on the differences in possible discrepancies among patients with varying types of malocclusions.[32]

CONCLUSION

The attempt to determine the influence of extraction of premolars on Bolton's ratios in South Indian population culminated in the observation of statistically significant difference in Bolton's ratios between the pretreatment and posttreatment recordings. The Bolton overall ratio decreased after extraction of premolars with maximum discrepancy in all first premolars and least discrepancy in all second premolars extraction. Statistically significant difference was also seen in the extraction pattern among males and females, thereby showing a difference in the extraction pattern that should be employed in males and females. In structuring a treatment plan that includes extraction of premolars, thorough care should be taken to determine the potentiality of creating significant discrepancies in tooth size after extraction.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Moimaz SA, Garbin AJ, Lima AM, Lolli LF, Saliba O, Garbin CA. Longitudinal study of habits leading to malocclusion development in children. BMC Oral Health 2014;14:96.
2. McLaughlin RP, Bennett JC, trevisi HJ. Systemized Orthodontic treatment mechanics. London: Mosby; 2001. p. 4, 6, 281.
3. Black GV. Descriptive anatomy of human teeth. 4th Ed. Philadelphia: S.S. White; 1902.
4. Neff CW. Tailored Occlusion with the Anterior Coefficient. Am J Orthod 1949;35:309-13.
5. Ballard ML. Asymmetry in tooth size: A factor in the etiology, diagnosis and treatment of malocclusion. Angle Orthod 1944;14:65-70.
6. Sherwood SR. The relation of upper anterior teeth to lower anterior teeth as present on plaster models of a group of acceptable occlusion. Angle Orthod 1952;22:91-7.
7. Bolton WA. Disharmony in tooth size and its relation to the analysis and treatment of malocclusion. Angle Orthod 1958:28:113-30.
8. Bolton WA. The clinical application of a tooth size analysis. Am J Orthod 1962;48:504-29.
9. Saatci P, Yukay F. The effect of premolar extractions on toothsize discrepancy. Am J Orthod Dentofacial Orthop 1997;111:42834.
10. Tong H, Chen D, Xu L, Liu P. The Effect of Premolar Extractions on Tooth Size Discrepancies. Angle Orthod 2004;74:50811.
11. Gaidyte A, Baubiniene D. Influence of premolar extractions on tooth size discrepancy. Part two: Analysis of Bolton values. Stomatologija 2006;8:259.
12. Jain AK, Garg N, Singh J, Ansari A, Sangamesh B. Mesiodistal crown dimensions of the permanent dentition of a North Indian population. Indian J Dent 2011;2:16-20.
13. Neff CW. The size relationship between the maxillary and mandibular anterior segments of the dental arch. Am J Orthod 1957;27:138-47.

14. Othman SA, Harradine NW. Tooth size discrepancy and Bolton's Ratios: A literature review. J Orthodont 2006;33:45-51.
15. Murray BL. A Fifth Column within normal dental occlusion. Am J Orthodont 1956;6:116-24.
16. Kanniyappan P, Saravanan B, Thulasiram E. Changes in traditional Bolton's ratio with various extraction combinations-An *in vitro* study. Biomed Pharmacol J 2015;8:647-53.
17. Kale PV, Chhajed DR, Khapli SS, Tripathi NR, Randhawa GK. Extraction: A Parameter in Bolton Ratio. J Dent Allied Sci 2015;4:3-7.
18. Kayalioglu M, Toroglu MS, Uzel I. Tooth-size ratio for patients requiring 4 first premolar extractions. Am J Orthod Dentofacial Orthop 2005;128:78-86.
19. Moorrees CF, Reed RB. Biometrics of crowding and spacing of the teeth in the mandible. Am J Phys Anthropol 1954:12:77-88.
20. Dahlberg G. Statistical methods for medical and biological students. New York: Interscience Publications; 1940.
21. Houston WJ. The analysis of errors in orthodontic measurements. Am J Orthod 1983;83:382-90.
22. Heusdens M, Dermaut L, Verbeeck R. The effect of tooth size discrepancy on occlusion: An experimental study. Am J Orthod Dentofac Orthop 2000;117:184-91.
23. Endo T, Ishida K, Shundo I, Sakaeda K, Shimooka S. Effects of premolar extractions on Bolton overal ratios and tooth-size discrepancies in a Japanese orthodontic population. Am J Orthod Dentofacial Orthop 2010;137:508-14.
24. 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.
25. Lama JH. Extraction choice: In the era of evidence based orthodontics. The Orthodontic Cyber Journal 2009.
26. Doris JM, Bernard BW, Kuftinec MM. A biometric study of tooth size and dental crowding. Am J Orthod 1981;79:326-36.
27. Puri N, Pradhan KL, Chandana A, Sehgal V, Gupta R. Biometric study of tooth size in normal, crowded, and spaced permanent dentitions. Am J Orthod 2007;132:279.e7-14.
28. Akinci Cansunar H, Uysal T. Comparison of orthodontic treatment outcomes in nonextraction, 2 maxillary premolar extraction, and 4 premolar extraction protocols with the American Board of Orthodontics objective grading system. Am J Orthod Dentofacial Orthop 2014;145:595-602.
29. Janson G, Maria FR, Bombonatti R. Frequency evaluation of different extraction protocols in orthodontic treatment during 35 years. Prog Orthod 2014;15:51.
30. Kašparová M, Procházka A1, Grajciarová L, Yadollahi M, Vyšata O, Dostálová T. Evaluation of dental morphometrics during the orthodontic treatment. Biomed Eng Online 2014;13:68.
31. Mangillo AD. The effect of four first premolar extractions on the posterior Bolton ratio. Master of Science in Dentistry, Saint Louis University; 2015.
32. Shastri D, Singh A, Tandon P. Bolton ratio in a North Indian population with different malocclusions. J Orthod Sci 2015;4:83-5.