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# Accuracy of in-built tip and effective tip expression capacity of different bracket sets with 19x25 stainless steel arch wire. A Cross-Sectional Evaluation

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## Abstract

**Introduction:** Variability and lack of precision in the bracket's manufacturing process can reduce the efficacy of the appliance and can therefore, force the clinicians to compensate for any dimensional inaccuracy through wire bending. This in-vivo exploratory investigation aimed to compare the tip values of the brackets from different companies with (MBT prescription) and amount of play (tip) produced by 19x25 stainless steel wire in 0.22 slot metal brackets.

**Methodology:** 18 pre-adjusted maxillary anterior bracket (3-3) from 3 different companies (A, B and C) were selected through purposive sampling technique and were mounted on modelling wax. Pictures were taken with DSLR (Canon D-600 with 100mm macro lens) camera. Bracket tip and play angles were measured with the help of IC Measure 3.1 software. Student's t-test, compared the tip values of all the maxillary anterior brackets of different manufacturers with the ideal tip values (MBT prescription). One-way ANOVA test and Post Hoc Tuckey test were used to identify and analyze any significant differences between tip and play values of different company bracket sets.

**Results:** : A statistically significant difference was observed between the ideal values and mean tip values of Company A (bracket# 21, 22, 13) and Company B (bracket # 11, 22) but the mean difference was clinically insignificant. However, Company C shows no significant difference. The (tip) play angles between the wire and bracket from difference companies show a significant difference ($P<0.05$). However, the difference was clinically insignificant. Also, there was a weak negative co-relation between brackets width and play angles ($P=0.191$).

**Conclusions:** This study's findings provide valuable information to the orthodontists, aiding them in making decisions regarding bracket selection for optimal treatment outcomes and also incorporate wire bending wherever necessary to compensate any differences between the claimed and measured tip values of the bracket sets available in market by various manufacturers.

**Keywords:** Bracket angulation (Tip); Slot Play; rectangular arch wire 19 *25

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## Introduction

A pivotal aspect of successful orthodontic outcomes, as proposed by Andrews and his six keys to normal occlusion, revolves around ensuring the correct axial inclination and angulation of the dentition for achieving functional occlusion, aesthetic improvements, and long-term stability.[1-3]

Before the advent of the Straight Wire Appliances (SWA), first, second, and third order bends were incorporated in the arch wire for correct teeth positioning. Contemporary appliances have revolutionized this process by integrating all the information either into the base or face of

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the bracket.[2,4] Andrew's research revealed a mutual relationship between tip and torque, (emphasizing that mesio-distal tip expression of the bracket plays a crucial role in conveying clinical tooth root angulation.[5] This angulation of maxillary incisors has a profound impact on smile aesthetics and is also a significant factor in anchorage preservation.[6,7]

The concept behind this SWA was that when a full dimension wire is inserted into a bracket slot the built-in tip & torque are expressed, the teeth should be guided to the ideal position. The tip is incorporated by angulating the bracket wings in mesio-distal plane and is expressed when the wire is bent against the bracket making a contact angle that generates a moment resulting in either mesial or distal tipping of the tooth.[8] Despite the information incorporated in clinical setting to achieve ideal occlusion and inter-cuspation arch, wire bending is still required.[9] Many factors influence tip expression including arch-wire stiffness (e.g., stainless steel, TMA), bracket width (large size), arch-wire dimension (19x25 s/s), slot size (0.022 slot), bracket stiffness and others.[2] When an undersized arch-wire is placed in a bracket slot, it may rotate clockwise or anticlockwise, creating play within the slot.[10] The degree of "play" increases with greater size difference between the arch-wire and the slot. Numerous studies have explored the clinical expression of bracket tip and torque. These studies have found variations in tip angulation among different bracket systems and highlighted the significance of slot dimensions and bracket design in achieving precise tip expression.

Lefebvre C et al. compared the bracket's slots dimensions and concluded that clinically, the oversize slot and the divergence of slot walls can result in an increase of wire-slot play, inducing a loss of torque control.[11] Study by Sohrab S. et al determined the torque expression capacity and play of 19x25 wire and 0.022 slot brackets from 6 different manufacturers and reported that brackets from Opal and arch wires from 3M showed least play.[10] Mendonca et al. conducted a study on 60 pre-adjusted (Roth prescription) steel anterior brackets from 3 various manufacturers and reported a variation in mean tip values ranging (2.13◦ and 3.90◦) between different bracket systems.[12] Plaza et al. evaluated 220 maxillary central incisors brackets, (MBT prescription), from 4 different manufacturers and found tip values to be significantly different from those declared by three different manufacturers, with a value range of 3.29◦ to 7.13◦.[13]

However, there is currently a lack of research regarding the built-in tip, effective tip expression capacity, and the degree of play associated with different metal bracket systems available in Pakistan. Therefore, this study aimed to investigate and quantify these aspects for 19x25 stainless steel wires used with 0.022 slot stainless steel bracket systems from different manufacturers available in Pakistan. Additionally, correlation between the width of brackets and Play (tip) was also assessed.

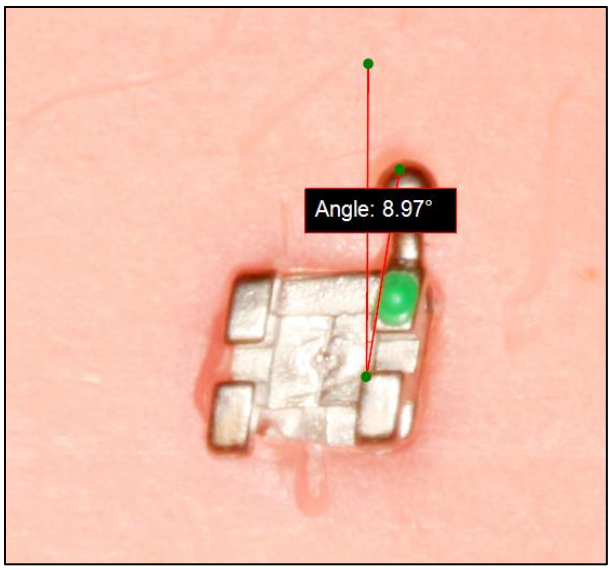


**Fig. I (A) -Tip of bracket: angle between long axis of bracket wing and base**

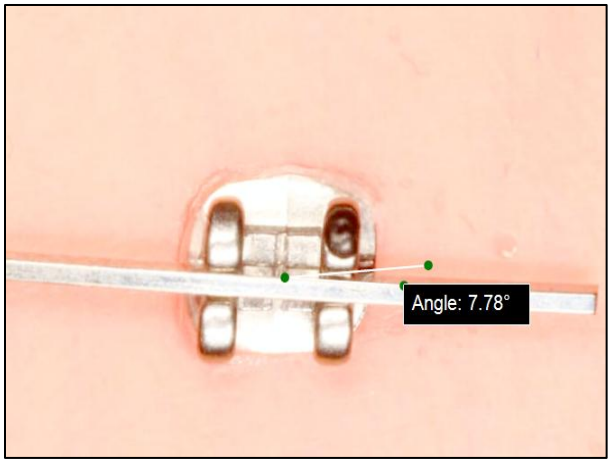


**Fig. I (B) - Play: angle formed between arch-wire and the bracket slot**

## Methodology

The present study was conducted as a pilot, in-vivo exploratory investigation to evaluate bracket tip and play angles across different manufacturers. Hence, a limited sample size was considered appropriate and justifiable with the tagged reasons. 1. To assess feasibility and measurement accuracy, 2. Total of 18 maxillary anterior brackets (three sets) provided multiple independent bracket-level measurements, allowing preliminary comparison with ideal MBT prescription values. 3. Standardized digital measurement using IC Measure 3.1 software ensured high precision, reducing measurement error and partially compensating for the smaller sample size. 4. The restricted sample size also adheres to ethical principles of minimal intervention, as increasing in-vivo sample numbers was not justified at this preliminary stage.

Ethical approval was sought from the Rehman Dental College (RCD) ethical committee board (EC Ref No. RCD-10-25-159) before commencing the research.

Total of eighteen pre-adjusted maxillary anterior teeth (3-3) brackets (MBT prescription) were sourced from three different manufacturers, (Company A,B &C). All brackets were selected by applying purposive sampling technique to conduct this study.

To facilitate the study, these brackets were then individually, securely affixed to the modeling wax. Figure I (A&B). High-quality photographs were captured using a Canon DSLR d-600 equipped with a macro lens (100mm), and a tripod stand was employed to ensure stability. The camera was adjusted to get all the shots perpendicular to the bracket slots. For the measurement of the play angle, a 19x25 stainless steel arch wire was inserted into the 0.022 -inch bracket slot in both clockwise and counterclockwise directions, and the average of these angles was calculated for each bracket. The calculation of the bracket tip and play angles was done with IC Measure 3.1 software. Figure I (A&B)

**Statistical analysis:**

Data were analyzed using SPSS version 25 (IBM Inc. Armonk, NY). Means and standard deviations were calculated for all quantitative variables. The Shapiro-Wilk test was employed to assess normal distribution of the data. Student's t-test was conducted to examine any difference between the measured tip and the ideal tip values stipulated by the MBT prescription. Furthermore, a one-way ANOVA and Post Hoc Tukey test were employed to discern any significant differences among the tip angles and play angles of 0.022" slot pre-adjusted brackets and wires among different bracket groups. A significance level of p value ≤0.05 was considered indicative of statistical significance. Pearson correlation analysis was employed to explore the correlation among bracket width and play angles. Intra and inter observer reliability was assessed using intra correlation coefficients (ICC).

## Result

ICC revealed a high-level of inter-examiner reliability (0.977) and intra-examiner reliability (0.975) for the measurements

suggesting that the two items in the scale are highly correlated and measure the same underlying construct effectively.

The skewness value was within ±1. Hence, the data was assumed to be symmetrical. The P-value for Shapiro-wilk test was greater than 0.05, which showed the data was normally distributed, so the normality assumption was met, and parametric tests were performed further.

The descriptive data of the study is presented in Table I.
Table II. shows the comparison of the tip of all the maxillary anterior brackets of different manufacturers with the ideal MBT prescription values. Brackets were assessed individually. The test revealed significant difference in the mean values for bracket # 21, #22 and #13 (Company A), #11 and# 22 (Company B) p <0.05. The mean value of the of the Bracket # 13 showed a negative value suggesting the mean value to be less than the reference group (-.614). Only the bracket #11 from (Company B) showed the highest mean difference with the ideal value (p< 0.00, MD=0.51) The (Company C) brackets showed insignificant difference with the MBT prescription values.

One-way ANOVA analysis for three bracket groups, showed a significant difference in tip values for bracket #13, #22, #23 within groups of bracket companies. Moreover, the Post hoc test revealed significant difference between Company A& C companies for bracket # 13 and #23 (p =0.00, P= 0.01) respectively. For bracket #22 a significant difference was found between Company A & C (p=0.01) and Company A & B (p=0.02). Table III

One-way ANOVA for three bracket groups, showed a significant difference in play angles of all maxillary anterior brackets within groups of various bracket companies. Moreover, Post hoc test showed significant difference between bracket #11, #22 showed significant difference between all three groups Company A & B*, Company A & C (p <0.01) Table IV

The coefficient correlation between play and width revealed a weak negative linear relationship. However, the correlation was not statistically significant between two variables (p=0.191). Figure II

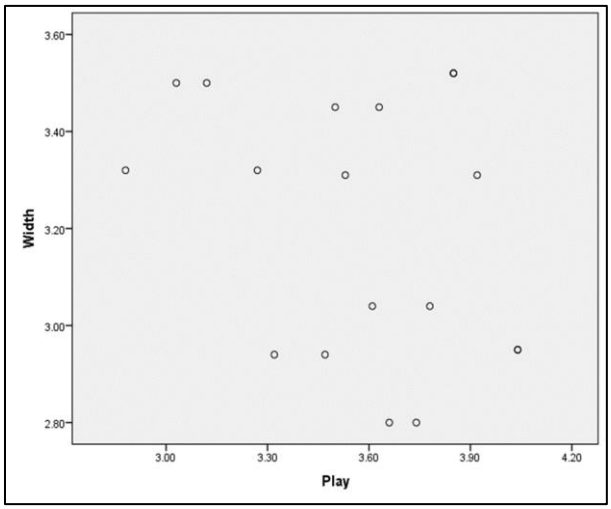


**Fig. II: Showing insignificant, negative and a weak correlation between play and width of the brackets.**

| Tooth | Maxillary | | Mandibular | |
|---|---|---|---|---|
| | Tip | Torque | Tip | Torque |
| Central incisor | +4° | +17° | 0° | −6° |
| Lateral incisor | +8° | +10° | 0° | −6° |
| Canine | +8° | −7°, 0°, +7° | 3° | −6°, 0°, +6° |
| First pre-molar | 0° | −7° | +2° | −12° |
| Second pre-molar | 0° | −7° | +2° | −17° |

**Fig. III: McLaughlin, Bennett, Trevisi (MBT) prescription of pre-adjusted appliance**

| | Effective Tip of the brackets Mean ± SD | | | Play in the brackets Mean ± SD | | |
|---|---|---|---|---|---|---|
| **Bracket #** | **Company A** | **Company B** | **Company C** | **Company A** | **Company B** | **Company C** |
| **11** | 4.32 ± 0.38 | 4.51 ± 0.24 | 4.15 ± 0.49 | 3.03 ± 0.08 | 3.85± 0.21 | 3.50± 0.19 |
| **12** | 8.04 ± 0.28 | 8.04 ± 0.14 | 7.81 ± 0.55 | 3.47 ± 0.26 | 4.04 ± 0.15 | 3.74 ± 0.08 |
| **13** | 7.38 ± 0.29 | 7.92 ±0.41 | 8.22 ± 0.31 | 2.88± 0.11 | 3.53 ± 0.17 | 3.61± 0.20 |
| **21** | 4.37 ± 0.23 | 4.33 ± 0.35 | 4.20 ± 0.28 | 3.12 ± 0.20 | 3.85 ± 0.15 | 3.63 ± 0.10 |
| **22** | 8.52 ± 0.40 | 7.88 ± 0.25 | 7.85 ± 0.18 | 3.32 ± 0.21 | 4.04 ± 0.11 | 3.66 ±0.09 |
| **23** | 7.52 ± 0.39 | 8.04 ± 0.21 | 8.29 ± 0.31 | 3.27 ± 0.13 | 3.92± 0.15 | 3.78 ± 0.09 |

**Table I: Showing descriptive data of the effective tip and Tip play in MBT prescription brackets**

| BRACKET .NO | Bracket Companies | | | | | |
|---|---|---|---|---|---|---|
| | Company A | | Company B | | Company C | |
| | Sig. (2-tailed) | Mean Difference | Sig. (2-tailed) | Mean Difference | Sig. (2-tailed) | Mean Difference |
| **11** | 11 | .10 | .00* | .51 | .52 | .15 |
| **12** | .74 | .04 | .54 | .04 | .49 | -.18 |
| **13** | .010* | -.614 | .716 | -.072 | .185 | .22 |
| **21** | .02* | .37 | .10 | .33 | .18 | .20 |
| **22** | .04 * | .52 | .00* | 0.08 | .15 | -.14 |
| **23** | .047 | -.50 | .293 | .116 | .104 | .29 |

**Table II: Showing comparison of the effective tip values with the ideal MBT prescription values**

| | Tip values | | | | Play values | | | |
|---|---|---|---|---|---|---|---|---|
| | Company A | Company B | Company C | P value | Company A | Company B | Company C | P value |
| | Mean ±SD | Mean ±SD | Mean ±SD | | Mean ±SD | Mean ±SD | Mean ±SD | |
| **11** | 4.32±0.38 | 4.51±0.24 | 4.15±0.49 | | 3.03±0.08 | 3.85±0.21 | 3.50±0.19 | */**/*** |
| **12** | 8.04±0.28 | 8.04±0.14 | 7.81±0.55 | | 3.47±0.26 | 3.85±0.15 | 3.74±0.08 | * |
| **13** | 7.38±0.29 | 7.92±0.41 | 8.22±0.31 | ** | 2.88±0.11 | 3.53±0.17 | 3.61±0.20 | */** |
| **21** | 4.37±0.23 | 4.33±0.35 | 4.20±0.28 | | 3.12±0.20 | 3.85±0.15 | 3.61±0.10 | */** |
| **22** | 8.52±0.40 | 7.88±0.25 | 7.85±0.18 | */** | 3.32±0.21 | 4.04±0.11 | 3.66±0.09 | */**/*** |
| **23** | 7.52±0.39 | 8.04±0.21 | 8.29±0.31 | ** | 3.27±0.13 | 3.92±0.15 | 3.78±0.09 | */** |

**Table III: Showing (Inter and intra group comparison of tip and play values)**

## Discussion

This study aimed to compare the mean tip values of the brackets from different manufacturers (Company A, B & C) with the ideal (i.e., claimed tip values MBT prescription). The degree of tip play produced by 19x25 stainless steel, SS wire, in -metal bracket slot of 0.022*0.028 dimension and its correlation with the respective widths of the brackets were also measured.

The full expression of the built-in information in pre-adjusted brackets depends on numerous factors. One of the influential factors is precision in fabrication by the company that can impact the accurate positioning of teeth.[14] Generally, when an Orthodontist uses commercial brackets ("MBT or ROTH" prescription), there is an assumption that all the brackets possess identical information, that is anticipated to be expressed clinically and generate optimal and similar results. Ideally, the values claimed by the manufacturers related to the bracket prescription should match the ideal tip and torque values. However, the findings in our research contradict this notion.

Current study observed a statistically significant difference in mean tip values brackets # 21, #22 and #13 (Company A), #11 and# 22 (Company B) but the difference was clinically insignificant. Only the bracket #11 from company B showed the highest mean difference with the ideal value ($p< 0.00$, MD=0.51) There was a weak negative co-relation between bracket width and play angle (P=0.191).

In this study we opted for the photographic approach using (Canon DSLR d-600 equipped with 100 mm (about 3.94 in) macro lens) due to its ease of use and the availability of a high-resolution, capable of capturing the minute details of brackets and slot angles. Subsequently, IC Measure 3.1 Software was used to compute angles for bracket tip and play. Various methods have been employed in the literature, including capturing bracket slot images using an (calibrated Olympus BX51) optical microscope,[13] bonding bracket to artificial teeth and measuring angles with Image J 1.40 software and assessing bracket tip and torque based on images obtained from a digital stereo microscope LEICA® DMS 1000 (Leica Microsystems gmbh, Wetzlar, Ger-many).[15]

This study appears to be the first to assess and compare the measured tip values and play(tip) of brackets from various manufacturers. Although, several studies have been conducted on tip and torque expression and comparison with ideal values and norms. We cannot compare our study with the previous ones as to the best of our knowledge studies investigating pre-adjusted brackets (tip play) are lacking and also the testing protocols are different. Various studies have been conducted in the past to evaluate the tip and torque values of stainless-steel brackets according to ISO 27020:2019 norm, (sets tolerance limits for the dimensions of the bracket slot and the inbuilt torque and tip).[13] ®In another study, bracket dimensions and torque values were tested according to the DIN 13971-2 norm that provides a similar testing protocol as ISO 27020:2019 norm but with a different tolerance range.[15]

The results of the current study showed mean tip value range to be 4.15◦-4.51◦ for central incisors, 8.52◦ for lateral incisor and 7.38◦-8.22◦ for canine from three companies. Also, a significant difference in the mean tip values for bracket # (11, 21, 22 and 13) with the ideal values was observed with the ideal or claimed values for (A and B) company.

Likewise, study by Mendonca et al found differences in mean tip values of maxillary left central incisor and canine brackets from different companies (Morelli, GAC and Forestadent ) concluding despite having the same prescription name, various companies can exhibit significantly different angulation measurements.[12] Plaza et al. also evaluated MBT prescription, of only maxillary central incisors brackets and reported tip values to be significantly different from three

manufacturers out of four with a value range of 3.29◦ to 7. 13◦.[13] Similarly study by Awasthi et al. evaluated 0.22 in. metal brackets from 6 different manufacturers with MBT prescription and observed mean tip values to be significantly different from the declared values in all the bracket sets ranging from 1.67◦ to 6◦.[16] Laura et al conducted a study using right central incisor brackets from 12 different manufacturers. They concluded that the tip values were different from the ideal in seven sets however, none of the tip values exceeded the tolerance limits. According to that study the tip information is accurately incorporated in the bracket slot and depends on the precision of manufacturing process.[13]
Our study revealed a weak negative correlation between bracket width and play angle that was in accordance with study by Lefebvre C et al. They compared the bracket's slots dimensions of a and concluded that clinically the slot oversize and the divergence of slot walls cause an increase of wire-slot play, inducing a loss of torque control.[11]

Strengths of the current study include low method error, quantified by the inter and intra-operator reliability. Also, this study, to the best of our knowledge appears to be the first to compare the angulation and play of the brackets from various companies.

Our study did not include types of brackets in terms of material (ceramic /plastic) ligation method (elastomeric vs self-ligation), different slot dimensions (0.018 vs 0.022), material and size of wire (stainless steel vs Niti, 17x25 and 19x25). Additionally, we used a photographic method for estimating the engagement angle which may not be as sensitive as digital stereo microscope.

## Recommendations:

Considering the above limitations, further research is warranted to expand our understanding of bracket variability and its implications in orthodontic practice.

## Conclusion

- Statistically, significant differences were observed in the tip values maxillary anterior brackets compared to the ideal values in few brackets.
- For the tip values, Company A and B companies showed the most variation, but this difference was found to be clinically insignificant.
- Play (TIP) angles for (Company A, B & C) brackets, also exhibited statistically significant difference but they were also clinically insignificant.
- A weak negative and correlation between play angle and bracket width was observed.

These findings provide valuable information for orthodontists and suggest the need for careful bracket selection and despite having the same prescription (MBT), brackets from various manufacturers can exhibit significantly different angulation values. Any mismatch between the declared and the actual values of the respective bracket set can be compensated by wire-bending. Name of the companies is concealed as it is only pilot exploratory study.

## Ethical Approval

The study was approved by the Ethical Review Board of Rehman College of Dentistry (EC Ref No.RCD-10-25-159)

## Disclaimer

The author(s) received no financial support for the research, authorship, and/or publication of this article.

## Conflict of Interest

It is declared that the authors don't have any conflict of interest.

## Authors' Contribution

**SZ:** Data Collection, Initial draft

**AI:** Methodology, statistical analysis, proof reading, editing

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