

Evaluation of Slot Dimension Accuracy of Different Bracket Systems

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ABSTRACT

Objectives: To evaluate the dimensional accuracy of slot base width and slot top width of ten commercially available bracket systems and to investigate the slot profile.

Materials and Methods: 0.022-inch upper right central incisor stainless steel brackets of ten different bracket systems (Gemini (3M Unitek), Victory series (3M Unitek), Master Brackets (American Orthodontics), Microline (Tomy), Equilibrium (Dentaurum), Micro-LPTM (Modern Orthodontics), Sapphire™ (Modern Orthodontics), Mini 2000 (Ormco), Mini Diagonal (Leone) and Midi Diagonal (Leone)) were measured using a stereomicroscope to determine the slot base widths, slot top widths and slot profile.

Results and discussion: The slot widths of all bracket systems significantly differed from each other ($p < 0.001$). The slots of Equilibrium (Dentaurum), Midi Diagonal (Leone), Mini Diagonal (Leone), Victory (3M), Microline (Tomy) and Mini 2000 (Ormco) were oversized whereas the slot of Master brackets (American Ortho) were undersized. Midi Diagonal (Leone), Microline (Tomy) and Mini 2000 (Ormco) had parallel slot walls out of all the bracket systems studied.

Conclusion: The bracket slot dimensions could be inaccurate due to improper machining and this adversely affects the three-dimensional tooth movement.

Key words: Slot dimensions, slot profile, machining inaccuracy.

INTRODUCTION

Straight wire appliance was introduced by Andrew in 1970, who initially put forth his 6 keys to normal occlusion and then set forth to satisfy them with an appliance in which in and out, tip and torque features were incorporated in the brackets, and was termed as pre adjusted edgewise brackets.² Preadjusted edgewise bracket system has undergone a lot of evolutionary changes with respect to composition (metal, plastic and ceramic), slot size (0.018 and 0.022), bracket prescription (tip and torque values), base design features (weldable or bondable), mode of ligation (manually or self ligated brackets). These brackets are commercially marketed by different companies, incorporating various features, in an attempt to improve clinical performance and aesthetic considerations.³

Accuracy of slot can be evaluated by stereomicroscope, scanning electron microscope and microhardness tester-model. Studies point to the need for the introduction of regulatory standards of orthodontic products and therefore technical standards of orthodontic wires and brackets manufacturing were described. Since most orthodontic

devices are directly associated with the relationship between size and prescription of brackets and with the section and size of wires, it is important that professionals know more about the materials used in their daily clinical practice.

Companies responsible for the manufacture of orthodontic accessories do not usually indicate their possible size variations; however these variations exist and they are associated to the bracket/wire manufacturing process. Among the adverse effects of brackets and wires with altered size and geometry, the reduction of dental movements control and increasing friction in the bracket/wire interface stands out. Undesirable effects such as torque loss of upper and lower incisors ($5 - 10^\circ$) during space closure mechanics can be attributed to changes in the bracket slot size. The lack of standardization in the wire and bracket slots dimensions will also directly influence on the frictional resistance, hindering the sliding mechanics. The lack of standardization in the wire and bracket slots dimensions will also directly influence on the frictional resistance, hindering the sliding mechanics.⁴

MATERIALS AND METHODS

The present study was carried out in the Department of

Orthodontics & Dentofacial Orthopaedics, H.I.D.S (Paonta Sahib). In this study, ten upper right central incisor MBT prescription orthodontic metal brackets with 0.022" × 0.028" slot dimensions from each of the ten different bracket systems were taken, thus a total of one hundred brackets were studied. The bracket systems used for the study were: Gemini (3M Unitek), Victory series (3M Unitek), Master Brackets (American Orthodontics), Microline (Tomy), Equilibrium

exported, calibrated and measured with ‘dgsoft ProMed’ software. The slot dimension was calculated by drawing a line within the slot parallel to slot base and slot top (Fig 4). The slot-base width and top width were measured in millimeters and the values were converted into inches with a converter. The software used was accurate up to a least count of 1 micron or up to 5 decimals in inches.

Table 1: Mean difference percentages from required size of 0.022-inch.

BRACKET SYSTEM	SLOT WIDTH AT BASE (INCH)	SLOT WIDTH AT TOP (INCH)
	MEAN DIFFERENCE PERCENTAGE	MEAN DIFFERENCE PERCENTAGE
MASTER BRACKETS (AO)	-3.95%	-2.77%
EQUILIBRIUM (DENTAURUM)	0.5%	1.14%
SAPPHIRE (MO)	-0.68%	0.27%
MICRO-LP (MO)	-2%	0.73%
MIDI DIAGONALI (LEONE)	0.5%	0.86%
MINI DIAGONALI (LEONE)	0.77%	1.32%
GEMINI (3M)	-1.82%	0.82%
VICTORY (3M)	0.32%	1.09%
MICROLINE (TOMY)	0.45%	0.45%
MINI 2000 (ORMCO)	0.55%	0.64%
The slot width base of each brand was compared with the slot top width of the same brand itself (slot profile) to investigate the taper of the bracket slot profile (Table 2).		

(Dentaurum), Micro-LP™ (Modern Orthodontics), Sapphire™ (Modern Orthodontics), Mini 2000 (Ormco), Mini Diagonali (Leone) and Midi Diagonali (Leone).

The brackets were viewed under a stereomicroscope (Fig 1) at 40× magnification. Brackets were fixed to a glass slide using wax, and the wax allowed the brackets to be maneuvered in the stereomicroscope so that the bracket slots could be photographed at a perpendicular angle (Fig 2a, 2b). Proper orientation of the bracket slots was confirmed by reviewing the images (Fig 3).

Each bracket was scanned and captured individually in the stereomicroscope on the mesial side to produce a digital image. The images of the bracket’s mesial profiles were

OBSERVATIONS AND RESULTS

The data obtained were statistically analyzed using the SPSS software. The level of significance was predetermined at a level of 0.05. The data were subjected to descriptive analysis for mean, mean difference, standard deviation, standard error and significance of all variables. ANOVA was done for the comparison of slot base width and slot top width of ten different bracket systems and was also done for the intra-brand comparison of slot width at base and slot width at top to analyze the slot profile. Further, Post Hoc test was done for multiple comparisons between the different bracket systems. The

comparison of slot base width and slot top width of various bracket systems with the manufacturer's quoted 0.022-inch width dimension was done using One sample t test.

Graph 1 shows the mean **slot width at base and slot width at top** for Master brackets (American Ortho), Equilibrium (Dentaurum), Sapphire (Modern Ortho), Micro-LP (Modern Ortho), Midi Diagonali (Leone), Mini Diagonali (Leone), Gemini (3M), Victory (3M), Microline (Tomy) and Mini

DISCUSSION

Achieving a satisfactory inclination or torque of the incisors is important for the final esthetic result.⁵ Torque expression depends upon a number of factors including the size of the bracket slots and archwires. A number of studies have investigated the effects of various factors on torsional play. These include bracket and archwire material^{6,7} irregularities in tooth morphology,⁸ errors in bracket placement⁸ and bevelling of

Table 2: Comparison between Slot base width and Slot top width of the same bracket system (intra-bracket system comparison)			
BRACKET SYSTEM	SLOT WIDTH AT BASE VS SLOT WIDTH AT TOP (INCH)		
	MEAN DIFFERENCE	MEAN DIFFERENCE PERCENTAGE	SIG. (p value)
MASTER BRACKETS (AO)	-0.00026	-1.22%	<0.02*
EQUILIBRIUM (DENTAURUM)	-0.00014	-0.63%	0.002*
SAPPHIRE (MODERN ORTHO)	-0.00021	-0.96%	<0.05*
MICRO-LP (MODERN ORTHO)	-0.00006	-2.7%	<0.001**
MIDI DIAGONALI (LEONE)	-0.00008	-0.36%	0.19
MINI DIAGONALI (LEONE)	-0.00012	-0.54%	<0.05*
GEMINI (3M)	-0.00058	-2.61%	<0.001**
VICTORY (3M)	-0.00031	-1.39%	<0.001**
MICROLINE (TOMY)	0	0	1
MINI 2000 (ORMCO)	-0.00002	-0.09%	0.59
The mean difference is statistically significant at the <0.5* level and highly significant at <0.001** level.			

2000 (Ormco).

The quantification of dimensional error was done in terms of percentage on the basis of comparison of slot base width and slot top width of various bracket systems with the required 0.022-inch dimension (Table 1).

archwires.^{9,10} Kusy and Whitley¹¹ suggested that there should be an exact description of slot geometry and standardization in SI units. 0.018 inch (0.4572 mm) and 0.022 inch (0.5588 mm), are separated by four thousandths of an inch, a somewhat unusual description in a metric modern world, where the scientific community measures in millimeters and micrometres. The

binding angle between the wire and the bracket is also important, as resistance to sliding movement increases with the increase in contact angle between archwires and bracket. For this the bracket slot dimension and the archwires dimensions should be precise.^{12,13}

➤ **Slot width at base of various bracket systems:**

The results of the present study showed that the mean slot width at base was minimum for Master Brackets (American Ortho) (0.021130 ± 0.00017) inch and maximum for Mini Diagonali (Leone) (0.022170 ± 0.00011) inch.



Fig 1: Master stereoscopic microscope (Stereomicroscope)

The mean values of slot base width for Equilibrium (Dentaurum) and Leone group of the present study were 0.022110 inch and 0.022110 inch respectively and these values were similar to a study done by Karan Tangri et al¹⁴ as the values were 0.0222 inch and 0.022 inch respectively. In their study the mean value of slot base width of Sapphire (Modern Ortho) was 0.0209 inch whereas this measurement was 0.021850 inch in the present study. Vinaya S Pai et al¹⁵ in their study found the mean slot width at base for Victory (3M) to be 0.0219 inch and this was similar to the value of the present study. Dissimilar results were found in the study conducted by Daga et al.¹⁶ In their study, the slot width at the base of Master Brackets (American Ortho) was 0.0226 inch and this value was greater than the result (0.021130 inch) of the present study. The difference in the mean values of the studies could be due to interlot variation.

➤ **Slot width at top of various bracket systems:**

The slot width at top was minimum for Master brackets (American Ortho) (0.021390 ± 0.00027 inch) and maximum for Mini Diagonali (Leone) (0.022290 ± 0.00012 inch). A study done by Karan Tangri et al¹⁴ showed almost similar mean value for slot top width of Leone as the value in their study was 0.0227 inch and the mean slot width at top for Victory (3M) was equivalent to study performed by Vinaya S Pai et al¹⁵ as the value in their study was 0.0222 inch. Daga et al¹⁶ when measured slot width at the top of Master Brackets (American Ortho) bracket slot, the width was found to be 0.0238 inch and this finding was in contrast to the present study. The variation in the mean values of the studies can be due to interlot variation.



Fig 2a: Bracket mounted on glass slide.

In the present study various bracket systems were compared and statistically significant differences ($p < 0.001$) were found in the slot dimensions of various manufacturers. This finding was in agreement with the studies done by Karan et al¹⁴, Youngran et al¹⁷ and Laura et al¹⁸.



Fig 2b: Zoomed view of the glass slide

Thus, from the above findings it could be concluded that the Master brackets (American Ortho) had narrowest slot width at

base and at top whereas Mini Diagonali (Leone) had widest slot width at base and at top from all the bracket systems assessed in the present study.

➤ **Comparison of slot base width and slot top width of various assessed bracket systems with the standard dimension of 0.022 inch (Graph 2):**

In the present study, the slot base width and slot top width of various bracket systems on comparison with required assumed dimension of 0.022-inch showed statistically significant ($p < 0.05$) difference. The slot base widths and slot top widths of Equilibrium (Dentaurum), Midi Diagonali (Leone), Mini Diagonali (Leone), Victory (3M), Microline (Tomy) and Mini 2000 (Ormco) were significantly ($p < 0.05$) wider than claimed dimension (0.022-inch). Although the slot base width of Victory (3M) was wider than 0.022 inch but the p value was insignificant ($p = 0.191$). Whereas, the slot base width and slot top width of Master brackets (American Ortho) were significantly ($p < 0.001$) narrower than 0.022-inch.

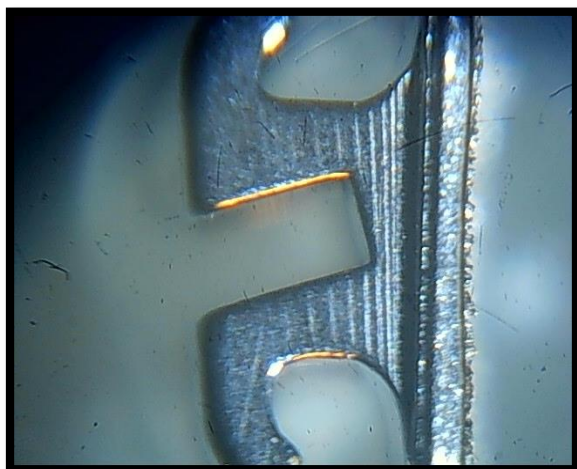


Fig 3: Bracket image captured by stereomicroscope.

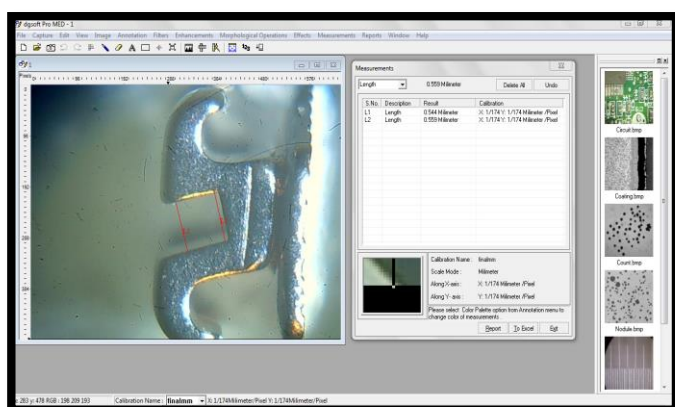
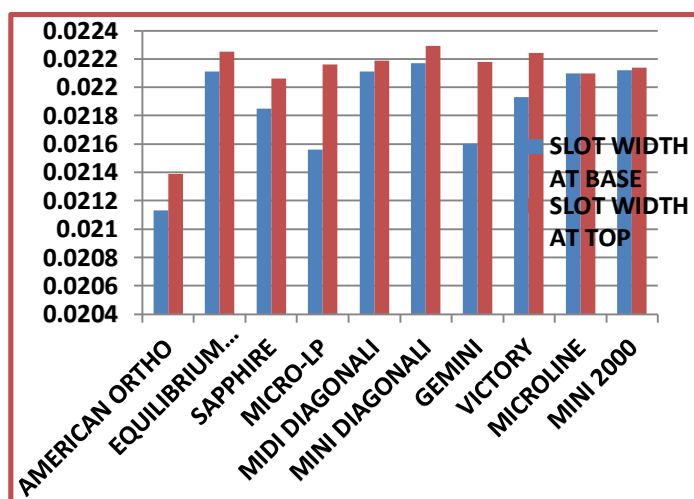


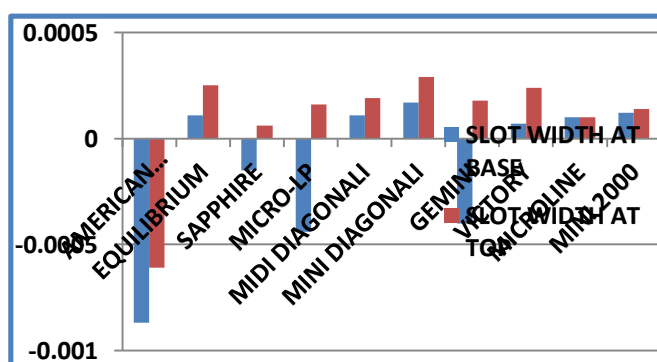
Fig 4: Screenshot showing measurement of slot base width and slot top width with 'dgsoft ProMed' software by drawing lines parallel to slot base and slot top between two points marked, in millimeters.

Micro-LP (Modern Ortho) and Gemini (3M) had significantly ($p < 0.05$) narrower slot base width but significantly ($p < 0.05$) wider slot top width than the standard 0.022 inch dimension. Even though the slot top width of Sapphire (Modern Ortho) was wider than the 0.022 inch dimension, the p value was insignificant ($p = 0.29$). The slot width at top of Sapphire (Modern Ortho) was closest to the claimed standard dimension.



Graph 1: Mean slot width at base and slot width at top of ten different bracket systems.

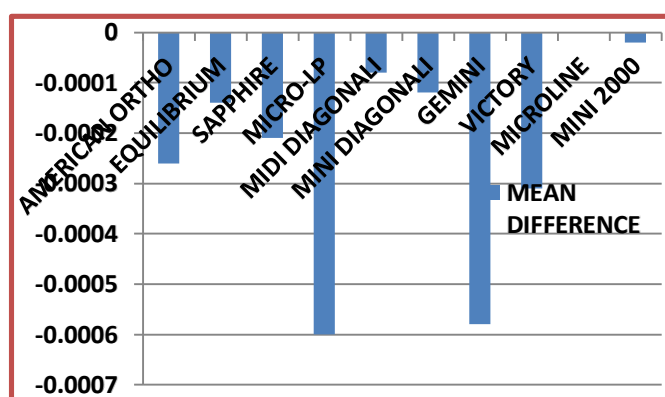
The quantification of dimensional inaccuracy was done in terms of percentages also on the basis of comparison of mean slot base width and mean slot top width of various bracket systems with the required 0.022-inch dimension. The slot base and top width of Master brackets (American Ortho) was narrower than the stated dimension by -3.95% and -2.77% respectively; whereas, the slot base and top width of Mini Diagonali (Leone) was wider than the stated dimension by 0.77% and 1.32% respectively.



Graph 2: Comparison of mean slot width at base and mean slot width at top of various bracket systems with claimed dimension of 0.022-inch.

The findings of the present study showed that the slots of all the brands under study were either wider or narrower than the standard claimed dimension. The slots of Equilibrium (Dentaurum), Midi Diagonali (Leone), Mini Diagonali (Leone),

Victory (3M), Microline (Tomy) and Mini 2000 (Ormco) were oversized whereas the slot of Master brackets (American Ortho) were undersized. With the obtained results it can be suggested that in terms of slot width at base and at top, the six bracket systems (Equilibrium (Dentaurum), Midi Diagonal (Leone), Mini Diagonal (Leone), Victory (3M), Microline (Tomy) and Mini 2000 (Ormco)) showed broader dimensions than indicated by the manufacturers and this finding was in agreement with the results reported by Cash¹⁹, John Seban⁹, Torstein and Meling¹⁰, Kusy¹¹, Pai VS¹⁵ and Bhalla²⁰ in their respective investigations.



Graph 3: Comparison between mean slot width at base and mean slot width at top of the same bracket system (intra-bracket system comparison).

The inaccuracy in slot width dimensions can be due to the error in method of manufacturing. Metallic brackets are fabricated by three main methods: casting, injection molding and milling, which may be used in combination.²¹ Molding exposes the material to expansion & shrinkage; milling can incorporate a rough grained surface. Shrinkage defects with casting occur when standard feed metal is not available to compensate for shrinkage as the thick metal solidifies.²²

Tolerance in manufacturing can affect the angle of deflection and therefore torque; the manufacturers of orthodontic appliances usually do not provide their tolerances and do not inform orthodontists of the smoothness of slot walls, of which there are few reports.³⁷ The loss of torque could be due to interaction between oversized brackets and archwire and this was illustrated by Siatkowski.²³ The effects of anterior torque force loss with brackets with a bigger than necessary slot size were illustrated by Siatkowski²³, who noted that maxillary and mandibular incisors may suffer an unexpected loss of torque force of 5-10°, and this is compared to 1.9 millimeters of lingual retrusion during retraction to close residual spaces. When protracting posterior teeth, if the mechanics depend upon moments generated at the incisor brackets with rectangular archwires, the above slot size errors can induce lingual tipping of the incisors. If the archwires are smaller

than their stated size, the impact is even worse. Conversely, if the slot dimensions are less than those stated by the manufacturer there would be less amount of clearance when using sliding mechanics and this would in turn cause greater friction and strain the anchor teeth.¹⁴

➤ **Comparison of slot base width with the slot top width of the same brand to evaluate slot profile (Graph 3):**

The results of the present study also showed that in general the size of the slot was greater at the top than at the base. The studies performed by Karan Tangri et al¹⁴, Youngran et al¹⁷ and Bhalla et al²⁰ were in agreement with this finding. In this study, the bracket system which showed similar slot width at base and top was Microline (Tomy) with 0 mean difference percentage.

The slot width base of each brand was compared with the slot top width of the same brand itself to investigate the taper of the bracket slot profile. The p value ($p < 0.05$) was significant for all bracket system's intra-brand comparison except for Midi Diagonal (Leone) ($p = 0.19$), Microline (Tomy) ($p = 1$) and Mini 2000 (Ormco) ($p = 0.59$). This finding stated that all bracket slots were divergent except Midi Diagonal (Leone), Microline (Tomy) and Mini 2000 (Ormco). The bracket slot of Microline (Tomy) was parallel with 0 taper and the bracket slot of Midi Diagonal (Leone) and Mini 2000 (Ormco) were almost parallel with the taper of -0.36% and -0.09% respectively.

There is no specific reason elicited in any study regarding the slot size inaccuracy. It can be due to any sort of error in the manufacturing process. None of the brands have specified the manufacturing process, composition and purity of the alloy in their brochure. Brackets made from different manufacturing process may have different dimension and different level of inaccuracy in dimensions. One of the reasons of slot distortion can be impurities present in the alloy. Lastly, slot width may get distorted during finishing of the final product.

The cutting of the bracket slot is done with the help of discs and with the passage of time these discs get blunt due to wear and tear, this further leads to improper cutting of the slots. Slots could remain uncut leading to unnecessary or excessive wire bending, or be cut at improper angles and depths leading to level misalignment.

Although most manufacturers do not state their engineering tolerances for bracket slot variations, manufacturing inaccuracies do exist as a result of errors in manufacturing processes and material parameters. Inaccurate machining of bracket slot dimensions and use of undersized archwires may directly and adversely affect the three-dimensional tooth positioning.²⁴ Though the bracket systems have multiple variations in how it is programmed, the effect on the mechanics may not vary to a great

extent.

Orthodontic clinicians should be aware that the preadjusted bracket and wire systems widely used in clinical practice may not produce the three-dimensional control required to produce an acceptable result. This may be particularly evident in cases that require incisor inclination correction, and the clinician should be aware that additional root torque may have to be added to the upper incisors to overcome inaccurate manufacturing dimensions.¹⁵

CONCLUSIONS

- There was considerable variation in slot widths between different bracket systems.
- Master brackets (American Ortho) had the narrowest and Mini Diagonal (Leone) had the widest slot width dimensions both at base and top from the various bracket systems studied.
- The slots of Equilibrium (Dentaurum), Midi Diagonal (Leone), Mini Diagonal (Leone), Victory (3M), Microline (Tomy) and Mini 2000 (Ormco) were oversized whereas the slot of Master brackets (American Ortho) were undersized.
- The slot top width of Sapphire (Modern Ortho) and slot base width of Victory (3M) were closest to the claimed standard 0.022-inch dimension
- In general, the slot base width was smaller than the slot top width in the bracket systems showing difference between the slot base width and slot top width for various bracket systems.
- All bracket slots were divergent except Midi Diagonal (Leone), Microline (Tomy) and Mini 2000 (Ormco). The bracket slot of Microline (Tomy) was parallel with 0 taper and the bracket slot of Midi Diagonal (Leone) and Mini 2000 (Ormco) were almost parallel with the taper of -0.36% and -0.09% respectively.
- Manufacturing anomalies might occur in a single bracket, throughout the sets of specific tooth brackets, or generally throughout an entire bracket series.

REFERENCES

1. Graber T.M: Development of a concept. Orthodontics Principles and Practice, 3rd Edn. Philadelphia: W.B. Saunders Company; 1992.
2. Graber T.M, Vanarsdall R.L.: Orthodontics Current Principles and Techniques. St. Louis C.V.Mosby Company; 1994.
3. Theodore Eliades, William Brantley: Orthodontic brackets. Orthodontic Materials International Edn ; 2001.
4. Gabriel Schmidt Dolci, Ana Maria Spohr, Eduardo Rigon Zimmer, Ernani Menezes Marchioro. Assessment of the dimensions and surface characteristics of orthodontic wires and bracket slots. Dental Press J Orthod. 2013 Mar-Apr; 18(2):69-75.
5. O'Higgins EA, Kirschen RH, Lee RT. The influence of maxillary incisor inclination on arch length. Br J Orthod 1999; 26:97-102.
6. Gioka C, Eliades T. Materials-induced variations in the torque expression of preadjusted appliances. Am J Orthod 2004; 125: 323-28.
7. Fischer-Brandies H, Orthuber W, Es-Souni M, Meyer S. Torque transmission between square wire and bracket as a function of measurement, form and hardness parameters. J Orofac Orthop 2000; 61:258-64.
8. Miethke RR, Melsen B. Effect of variation in tooth morphology and bracket position on first and third order correction with preadjusted appliances. Am J Orthod 1999; 116:329-35.
9. Sebanc J, Brantley WA, Pincsak JJ, Conover JP. Variability of effective torque as a function of edge bevel on orthodontic arch wires. Am J Orthod 1984; 86:43-51.
10. Meling TR, Odegaard J. On the mechanical properties of square and rectangular stainless steel wires tested in torsion. Am J Orthod 1997; 111:310-20.
11. Kusy RP, Whitley JQ. Assessment of second-order clearances between orthodontic archwires and bracket slot via the critical contact angle for binding. Angle Orthod 1999; 69: 71-80.
12. Kusy RP. 'Two' much of a good thing? Then let's pick one slot size and make it metric. Am J Orthod 2002; 121:337-38.
13. Peck S. Orthodontic slot size: it's time to retool. Angle Orthod 2001; 71:329-30.
14. Tangri K, Kumar P, Sharma P, Kumar K, Bagga DK, Sharma R. A Comparison of the Accuracy of 0.022 Slots at Face, Base and Mesial and Distal Surface of Brackets marketed by Different Manufacturers. J Ind Orthod Soc 2012; 46(3):132-136.

15. Pai VS, Pai SS, Krishna S, Swetha M. Evaluation of Slot Size in Orthodontic Brackets: Are Standards as Expected? J Ind Orthod Soc 2011; 45(4):169-174.
 16. Daga PN, Karandikar GR, Patni V, Karandikar AG, Doshi S. A comparative evaluation of accuracy of Mclaughlin Bennet Trevisi prescription of six commercially available orthodontic metal brackets: An *in vitro* study. J Indian Orthod Soc 2017; 51: 264-71.
 17. Youngran Lee; Dong-Yul Lee; Yoon-Ji R. Kim. Dimensional accuracy of ceramic self-ligating brackets and estimates of theoretical torsional play. Angle Orthod. 2016; 86: 804–809.
 18. Laura Elizabeth Martínez Pérez, Roberto Ruíz Díaz, Gerardo Ruiz Botello, Sergio Padilla Olvera. Slot tolerance from three different commercial brands of brackets. Revista Mexicana de Ortodoncia, 2014; 2(1):38-41.
 19. Cash A, Good S, Curtis R, McDonald F. An evaluation of slot size in orthodontic brackets-are standards as expected? Angle Orthod. 2004; 74:450–453.
 20. Nidhi B. Bhalla, Sarah A. Good, Fraser McDonald, Martyn Sherriff and Alex C. Cash. Assessment of slot sizes in self-ligating brackets using electron microscopy. Aust Orthod J 2010; 26: 38–41.
 21. Spiros Zinelis, Olga Annousaki, Margarita Makou, Theodore Eliades. Metallurgical Characterization of Orthodontic Brackets Produced by Metal Injection Molding (MIM). Angle Orthod 2005; 75:1024–1031.
 22. Eshan Awasthi, Narendra Sharma, Sunita Shrivastav, R.H. Kamble. Evaluation and comparison of various prescription specifications and slot distortion of pre-adjusted edgewise brackets manufactured by different companies available in India. Int J Cur Res Rev May 2015; 7 (9).
 23. Siatkowski R. Loss of anterior torque control due to variations in bracket slot and archwire dimensions. J Clin Orthod 1999; 33: 508-510.
- Matasa Claude G. Flaws in bracket manufacturing. J Clin Orthod 1990; 149-52.