IN VITRO COMPARATIVE EVALUATION OF SLOT SIZE AND IN-BUILT TORQUE OF DIFFERENT PASSIVE SELF-LIGATING BRACKET SYSTEMS: A STEREO-MICROSCOPIC STUDY

Dr. Zahid Manzoor[1*], Dr. Shipra Nagar[2], Dr. Ashish Kumar[3], Dr. Mansi Singh[4], Dr. Neha Agrawal[5], Dr. Vimal Thareja

Abstract.
The purpose of this study was to measure and compare the slot dimensions & inbuilt torque of 0.022″ × 0.028″ slot passive self-ligating brackets of five different manufacturers.

Material and method: 200 brackets from five different manufacturers were taken for evaluation of slot dimensions with a stereomicroscope (alco 0745t range/capacity- 10x -450x) The images obtained were calibrated with a software quickphoto micro 3.2. The bracket slot at the base and the face were measured.

Results: All the bracket slots measured in this study were found to be oversized compared to the standard value (0.022"). Slot dimension at base and at face were found to be coinciding except in group 3(Ortho Organizer) where the mean value at face was found to be higher than at base, indicating divergence in slot profile. The mean values for built in torque were less in all the brackets. The maximum variation in built in torque was seen in group 5 (Modern Orthodontics) (24%) & the least variation in group 2 (Ormco) (1%)

Conclusion: Slot dimensions showed higher values than the manufacturer declared standard in all groups with the maximum variation seen in group 3 (ortho organizer) (11-12%) & the least variation in group 1 (3m unitek) (10%) The maximum variation in built-in torque was seen in group 5 (modern orthodontics) (24%) & the least variation in group 2 (Ormco) (1%)

[1]Post Graduate Student, Department of Orthodontics and Dentofacial Orthopedics, Kalka Dental College, Meerut. drzahidmnzoor@yahoo.com
[2]Professor and Head of Department, Department of Orthodontics and Dentofacial Orthopedics, Kalka Dental College, Meerut. shipray@yahoo.com
[3]Senior Lecturer, Department of Orthodontics and Dentofacial Orthopedics, Kalka Dental College, Meerut. ashish.idst@gmail.com
[4]Senior Lecturer, Department of Orthodontics and Dentofacial Orthopedics, Kalka Dental College, Meerut. manshi.singh1996@gmail.com
[5]Professor, Department of Orthodontics and Dentofacial Orthopedics, Kalka Dental College, Meerut. nehagem007@gmail.com
[6]Reader, Department of Orthodontics and Dentofacial Orthopedics, Kalka Dental College, Meerut. drvimalthareja@gmail.com

***Corresponding Author:** Dr. Zahid Manzoor
[1]Post Graduate Student, Department of Orthodontics and Dentofacial Orthopedics, Kalka Dental College, Meerut. drzahidmnzoor@yahoo.com

DOI: 10.48047/ecb/2023.12.si5a.0462

INTRODUCTION:

A bracket is defined as a device that projects horizontally to support something. In orthodontics all of the devices that project horizontally to support an arch wire could be called brackets. The term brackets came into use in orthodontics when Dr. Angle introduced the ribbon arch appliance in the year 1916. The wave of design changes continued to mount and a variety of bracket designs are available nowadays.

Andrews published his landmark article in 1972 and subsequently designed an appliance based on his findings. However, soon after the introduction of the pre-adjusted appliance, it became clear that bracket systems required a whole new program of treatment mechanics and force levels to fully utilise their potential. In turn, the new treatment mechanics and force levels brought about a need for modification to the bracket systems.

Although the concept of self-ligation was introduced in orthodontics several decades ago, it was only in the last 20 years that these appliances became available in their current form. In these days of multifaceted versatile brackets with self-ligating systems of all sorts, it is forgotten that concept of light force & large inter-brackets distance being used as mechanical advantage, has been around for many years. We seemed to have given in to the esthetics component at the sacrifice of biomechanics. In the last two decades, a consensus has emerged on the potential core advantages of self-ligation. These can be summarized as- faster arch wire removal & ligation, more certain full arch wire engagement, less or no chairside assistance & low friction between brackets and arch wire.

In the year, 2020, A. Matthew et al concluded in their study on passive self ligating brackets that there was a need to study size & inbuilt torque of bracket design from different companies and therefore, the present study was conducted to compare the slot dimension & inbuilt torque of entire series of passive self-ligating brackets through the stereomicroscope.

MATERIAL & METHODS:

The present invitro, non-pharmacological, single-centred, single-operator, cross-sectional analytical study was approved by the institutional ethical board (KDC/I76/2020/0876). Sample size was calculated by G Power Software (Version 3.1) and were found to be 200 sample of passive self-ligating brackets from five different manufacturers & were divided into five different groups. Measurement was taken at the base & face for the bracket slot dimensions & In-built torque. A new set of unused set of brackets were selected which were selected directly from the manufacturer.

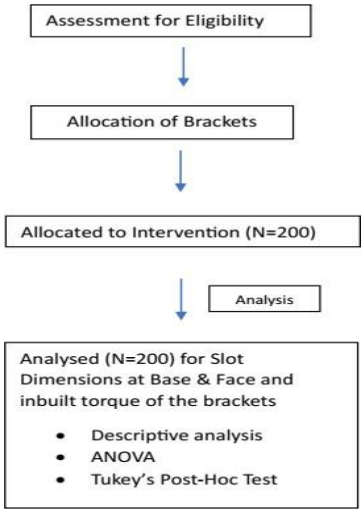
EVALUATION PROCEDURE:

New set of brackets were selected randomly and mounted on wax strip within vertical orientation. Slides were mounted on microscope (ALCO 0745T Range/Capacity: 10x-450x) (Fig. 3) and were viewed on magnification of 20x so that a sharp, clear image was viewed on screen and captured individually in stereomicroscope to produce a digital image. To standardize the image Quick-Photo Microscope (Version 3.2) were used, which was accurate at least count of 1micron or up to 5 decimals in inches.

Slot dimensions & Inbuilt torque of the samples of all five groups were recorded in Microsoft Excel Software (Version 2010) and their measuring value were recorded in Inches & degrees.

METHODOLOGY:

Enrollment



MEASUREMENT OF SLOT DIMENSION: AT BASE

The descriptive statistics of slot dimensions at base show that measurements for all brackets showed increased value compared to the standard value of 0.22 slot dimensions (Table 1).

MEASUREMENT OF SLOT DIMENSION: AT FACE

The descriptive statistics of slot dimensions at face show that measurements for all brackets showed increased value compared to the standard value of 0.22 slot dimensions (Table 2).

STATISTICAL ANALYSIS

Sample size was calculated by G*Power Software (Version 3.1.9.6), the power of the study kept at 95% with significance level of 5% (α=0.05) and effect size at 1.51, Calculation based on mean & standard deviation (SD) of the previous study (0.0229±0.00035).[17] The required sample was 200 brackets.

All the parameters of the patients were summarized as mean & SD. The data were collected & tabulated in Microsoft Excel (Version 10) and statistically analyzed using Statistical Package for social Science Software (SPSS, Version 22.0)

RESULTS

MEASUREMENT OF SLOT DIMENSION: AT BASE

The descriptive statistics of slot dimensions at base show that measurements for all brackets showed increased value compared to the standard value of 0.22 slot dimensions (Table 1). The mean value of the slot dimensions at Base was found to be 0.02514±0.000746.

MEASUREMENT OF SLOT DIMENSION: AT FACE

The descriptive statistics of slot dimensions at face show that measurements for all brackets showed increased value compared to the standard value of 0.22 slot dimensions (Table 2). The mean value of the slot dimensions at Face was found to be 0.025±0.000775.

MEASUREMENT OF INBUILT TORQUE:

On analysis of inbuilt Torque, all brackets were found to have lesser value of torque than those described by the manufacturers, with all the brackets showing a variation of approximately 1to 24 percentage from the standard values (Table 3).

DISCUSSION:

The advent of Andrews' straight wire philosophy during the 1970s was a revolutionary breakthrough in orthodontics. Despite the advancements in orthodontic techniques, preadjusted edgewise appliances with standard size, siamese, stainless steel brackets that are conventionally ligated are still widely used by orthodontists worldwide.

However, using brackets with oversized slots can have negative effects on anterior torque loss, as demonstrated by Siatkowski[10]. When these appliances are used for protracting posterior segments during space closure, unexpected torque loss in upper and lower incisors can occur. During space-closing protraction, a loss of torque in the anterior teeth can lead to a backward movement of the incisal edges by around 1.9 mm, with the torque loss ranging from 5 to 10 degrees.

The process of manufacture is a significant determinant of the slot dimensions and built-in torque precision of brackets. Metal Injection Moulding (MIM) is presently the most commonly utilized method for manufacturing bracket bodies. This is because milling or machining and investment casting are less prevalent due to their longer production cycles and lower cost effectiveness.

According to Gioka and Eliades'[7] systematic review, the slot surfaces of brackets exhibited striations and microstructural defects, which appear to be a result of milling techniques and may prevent complete wire insertion in the slot of the bracket due to the rough surface produced. Moulding could also contribute to this problem.

Subsequent research could investigate the effects of varying bracket alloys, debinding techniques, and sintering parameters on the precision of orthodontic bracket slot size and builtin torque. The present study's objective was to assess the slot dimensions and built-in torque of five distinct brands of orthodontic brackets, namely 3M Unitek, Ormco, Ortho Organizer, JJ Orthodontics, and Modern Orthodontics.

The study analyzed a total of 200 brackets, with 40 brackets from each manufacturer. The measured slot dimensions were assessed using ANOVA and post hoc analysis. This study is distinctive in comparing self-ligating brackets from five different brands, which is a criterion that has not been explored in many studies.

The study findings indicate that the measured slot heights of the brackets were greater than the intended size, and a significant difference was observed in the slot size of JJ Orthodontics & Ortho Organizer brackets when compared to the ideal slot size of 0.022". The cause of this difference may be attributed to manufacturing errors.

In addition, a comparison between the nominal prescription values and the torque values measured revealed that JJ Orthodontics & Modern Orthodontics brackets had significantly lower torque values than the prescribed values.

LIMITATION AND FUTURE SCOPE

The use of this study was not done in accordance with the oral condition; furthermore, there is need to study these subjects under clinical conditions to provide the better understanding of clinical use of this study.

CONCLUSION:

The study's conclusions are:

- The ideal value for slot dimensions at base and at face are 0.022". However, in the present study, the mean values of the slot dimensions at base and face was found to be

0.02514 ± 0.000746 and 0.02514 ± 0.000775 respectively.

- Slot dimension values at base and at face were found to be coinciding except in **Group 3** where the mean value at face was found to be higher than at base, indicating **divergence** in slot profile.
- In all groups, the slot dimensions at the base and face were found to exceed the manufacturer's stated standards with the maximum variation seen in Group 3 (Otho Organizer) (11-12%) followed by Group 5 (Modern Orthodontics) (11.7%), Group 4 (JJ Orthodontics) (11.5%), Group 2 (Ormco) & the least variation in Group 1 (3M Unitek) (10%)
- On analysis of in-built torque, all brackets were found to have **lesser** values of torque than those declared by the manufacturer, with all the brackets showing a variation of approximately **1 to 24%** from the standard values.

FIGURES

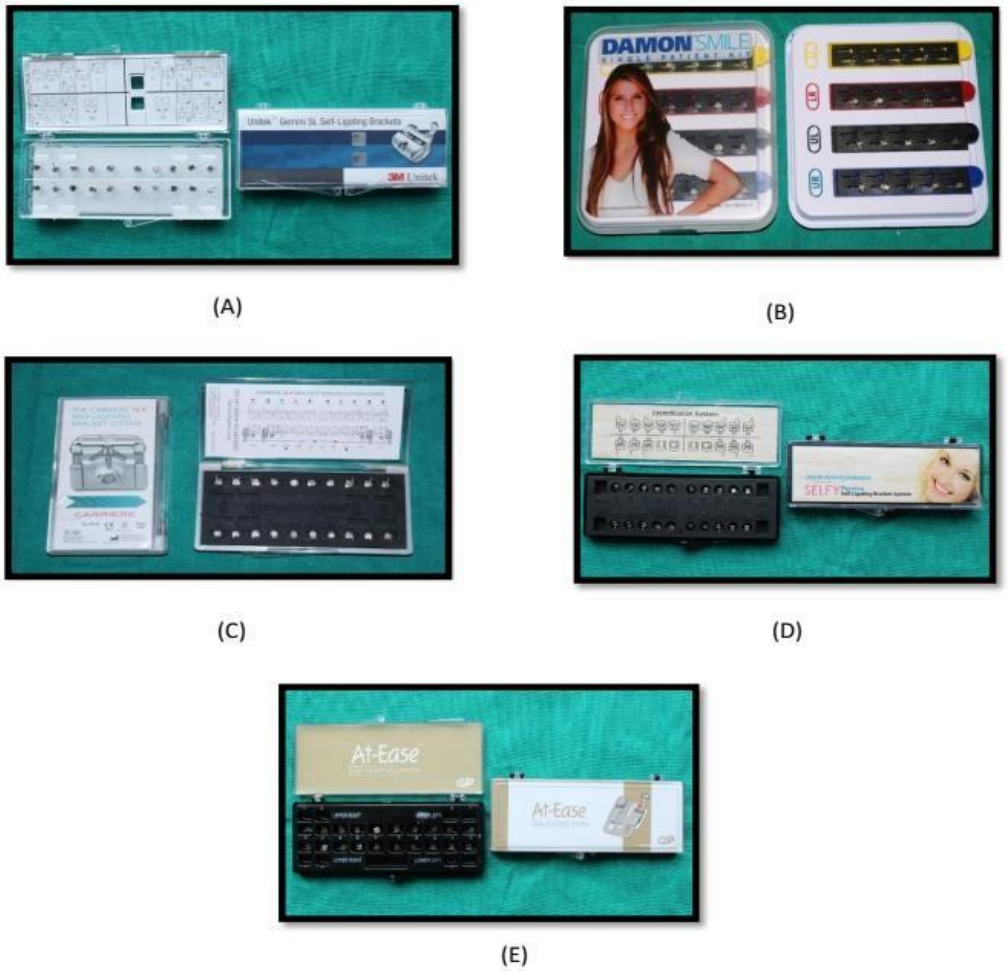


Fig. 1. (A) Gemini SL™ 0.022" × 0.028" (B) Damon Q™ 0.022″ × 0.028″ (C) Carriere SLX™ 0.022″ × 0.028″ (D) Selfy passive SL™ 0.022″ × 0.028″ (E) At Ease passive SL™ 0.022″ × 0.028″

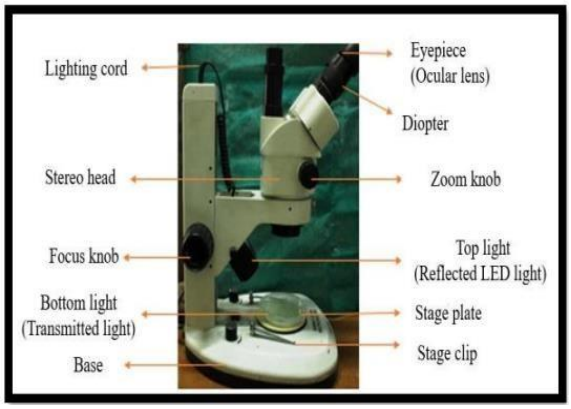


Fig. 2 Measuring Stereomicroscope (ALCO 0745TRange/Capacity-10x-450x)

Fig. 3 Stereomicroscope, measuring software & brackets mounted on stereomicroscope slide

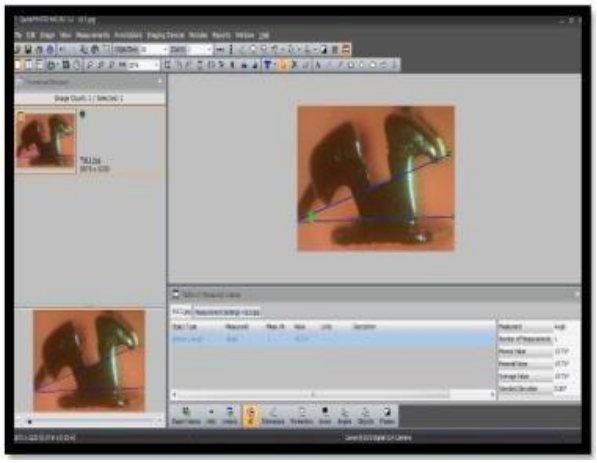


Fig. 4 Magnified digital image uploaded on software for analysis of torque

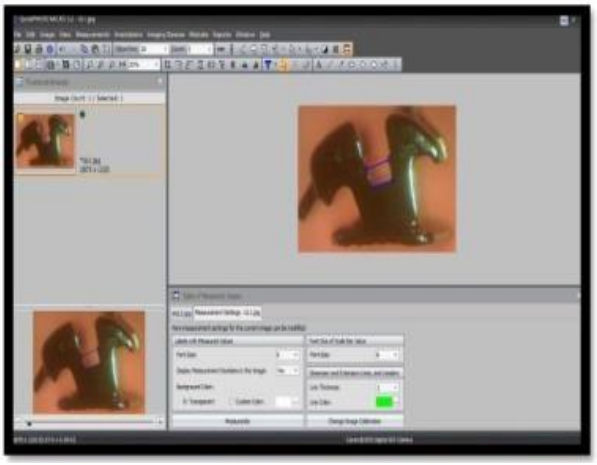


Fig. 5 Magnified digital image uploaded on software for analysis of slot dimension

TABLES

MEASUREMENTS OF SLOT DIMENSIONS: AT BASE

TABLE 1 Descriptive Statistics (N=40) for Slot Dimensions At Base

Group	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Group 1	40	0.02492	0.000581	0.000092	0.02440	0.02477	0.023	0.026
Group 2	40	0.02362	0.000755	0.000119	0.02418	0.02466	0.023	0.026
Group 3	40	0.02452	0.000702	0.000111	0.02496	0.02541	0.023	0.026
Group 4	40	0.02536	0.000660	0.000104	0.02470	0.02512	0.024	0.026
Group 5	40	0.02590	0.000785	0.000124	0.02470	0.02521	0.024	0.026
Total	200	0.02514	0.000746	0.000053	0.02471	0.02491	0.023	0.026

• **Inference:** Descriptive statistics of slot dimensions at base show that measurements for all brackets showed increased value compared to the standard i.e 0.022”

MEASUREMENTS OF SLOT DIMENSIONS: AT FACE

Table 2: Descriptive Statistics (N=40) For Slot Dimensions At Face

Group	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Group 1	40	0.02492	0.000623	0.000099	0.02472	0.02511	0.024	0.026
Group 2	40	0.02362	0.000726	0.000115	0.02438	0.02485	0.023	0.026
Group 3	40	0.02552	0.000669	0.000106	0.02530	0.02573	0.024	0.027
Group 4	40	0.02536	0.000763	0.000121	0.02511	0.02560	0.024	0.027
Group 5	40	0.02590	0.000756	0.000119	0.02506	0.02554	0.024	0.027
Total	200	0.02514	0.000775	0.000055	0.02503	0.02525	0.023	0.027

• **Inference:** Descriptive statistics of slot dimensions at face show that mean readings of slot dimensions of all groups showed an increased value compared to the standard i.e 0.022”

MEASUREMENTS OF IN-BUILT TORQUE

Table 3: Means & standard deviations of measured in-built Torque (In Degrees) Of Preadjusted Edgewise Bracket Groups

ARCH	Tooth N=40 no.	Group 1 (MEAN±SD)	Group 2 (MEAN±SD)	Group 3 (MEAN±SD)	Group 4 (MEAN±SD)	Group 5 (MEAN±SD)
Maxillary	11, 21 4	15.39±0.28(+17) *	14.86±0.16(+15) *	15.12±0.62(+17) *	15.25±0.39 (+16) *	15.15±1.23 (+16) *
	12, 22 4	8.15±0.72 (+10) *	5.17±0.39(+6) *	9.07±0.41 (+10) *	7.66±042 (+8) *	8.33±0.56 (+9) *
	13, 23 4	0.64±0.41 (0) *	6.24±0.64(7°)*	0.75±0.61 (0) *	5.81±0.46 (7°) *	5.89±0.86 (0) *
	14, 24 4	5.60±0.52 (-7) *	10.43±0.57(-11) *	5.43±0.78 (-7) *	5.22±0.34 (-7) *	5.31±0.71 (-7) *
	15, 25 4	5.79±0.53 (7) *	10.56±0.78(11) *	5.47±0.53 (7) *	5.24±0.53 (7) *	5.75±0.53 (7) *
Mandibular	31, 32 41,42 8	4.90±0.50 (-6) *	2.12±0.35(-3) *	4.86±0.49 (-6) *	4.67±0.52 (-6) *	4.80±0.47 (-6) *
	33, 43 4	0.54±0.41 (0) *	6.23±0.12 (-7°)*	0.55±0.64 (0) *	4.59±0.46 (-6°)*	0.83±0.89 (-6) *
	34, 44 4	10.85±0.54 (-12) *	10.82±0.37(-12) *	9.11±3.33 (-12) *	11.50±2.06 (-12) *	9.77±0.81 (-12) *
	35,45 4	15.08±1.18 (-17) *	16.32±0.48(-17) *	13.97±1.68 (-17) *	14.59±0.72 (-17) *	14.99±1.06 (-17) *

*prescribed values of in built torque as declared by manufacturer.

Inference: Means and standard deviations of measured inbuilt torque values of preadjusted edgewise bracket groups show that all values are lesser than those claimed by the manufacturer with all brackets showing a variation of approximately 1 to 24% from the standard values.

REFERENCES:

1. Cash AC, Good SA, Curtis RV, McDonald F. An evaluation of slot size in orthodontic brackets—are standards as expected? Angle Orthod. 2004 Aug;74(4):450-3.
2. Park JS, Song IT, Bae JH, Gil SM, Kang KH. Comparison of slot sizes and parallelism of

metal brackets manufactured through metal injection molding and computerized numerical control. Korean J. Orthod.2020 Nov 25;50(6):401-6.
3. Brown P, Wagner W, Choi H. Orthodontic bracket slot dimensions as measured from entire bracket series. Angle Orthod. 2014 Sep 29;85(4):678-82.
4. Kusy RP, Whitley JQ. Assessment of second-order clearances between orthodontic archwires and bracket slots via the critical contact angle for binding. Angle Orthod. 1999;69(1):71–80.
5. Bhalla NB, Good SA, McDonald F, Sherriff M, Cash AC. Assessment of slot sizes in selfligating brackets using electron microscopy. Aust. Orthod. J. 2010 May;26(1):38.
6. 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(4):258–65.
7. Gioka C, Eliades T. Materials-induced variation in the torque expression of preadjusted appliances. Am J Orthod Dentofacial Orthop. 2004;125(3):323–328.
8. Meling TR, Ødegaard J, Seqner D. On bracket slot height: a methodologic study. Am J Orthod Dentofacial Orthop. 1998;113(4):387– 93.
9. Creekmore TD, Kunik RL. Straight wire: the next generation. Am J Orthod Dentofacial Orthop. 1993;104(1):8–20.
10. Siatkowski RE. Loss of anterior torque control due to variations in bracket slot and archwire dimensions. J Clin Orthod 1999;33(9):508–10.
11. Proffit W. Contemporary Orthodontics. 4th ed. St. Louis, Mo:Mosby Elsevier; 2007.
12. Bennett J. Fundamentals of Orthodontic Treatment Mechanics. 1st ed. London, UK:LeGrande Publishing; 2014.
13. 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. Indian Orthod. Soc 2012 Jul 1;46(3):132.
14. Sebance J, Brantley WA, Pincsak JJ, Conover JP. Variability of effective root torque as a function of edge bevel on orthodontic arch wires. Am J Orthod Dentofacial Orthop. 1984;86:43-50.
15. Attia KH, Elkordy SA, ElKoussy M, Abouelezz AM. Are self-ligating brackets' slots dimensions accurate? Int. Orthod. 2018 Dec 1;16(4):613-22.
16. Huang Y, Keilig L, Rahimi A, Reimann S, Eliades T, Jäger A, Bourauel C. Numeric modeling of torque capabilities of self-ligating and conventional brackets. Am J Orthod Dentofacial Orthop. 2009 Nov 1;136(5):638-43.
17. Mathew, A., Kumar, H. K., & Shetty, S. (2020). A Comparative Study of the InBuilt Torque and Slot Size of MBT Prescription Bracket of Different Manufacturing Companies: A Stereo-Microscopic Study. J. Indian Orthod. Soc. 54(4), 297–303.
18. Flores DA, Choi LK, Caruso JM, Tomlinson JL, Scott GE, Jeiroudi MT. Deformation of metal brackets: a comparative study. The Angle Orthod. 1994 Aug;64(4):283-90.
19. Kusy RP, Whitley JQ. Influence of archwire and bracket dimensions on sliding mechanics: derivations and determinations of the critical contact angles for binding. Eur. J. Orthod. 1999 Apr 1;21(2):199-208.
20. Peck S. Orthodontic slot size: it's time to retool. Angle Orthod. 2001 Oct;71(5):329-30.
21. Epstein MB. Benefits and rationale of differential bracket slot sizes: the use of 0.018-inch and 0.022-inch slot sizes within a single bracket system. Angle Orthod. 2002 Oct;70(5):326-30.
22. Kang BS, Baek SH, Mah J, Yang WS. Three-dimensional relationship between the critical contact angle and the torque angle. Am J Orthod Dentofacial Orthop. 2003 Jan 31;123(1):64-73.
23. Sernetz F. Standardization of Orthodontic Products—Does it Make Sense? J Orofac Orthop /Fortschritte der Kieferorthopädie. 2005 Jul 1;66(4):307-18.
24. Demling A, Dittmer MP, Schwestka-Polly R. Comparative analysis of slot dimension in lingual bracket systems. Head Face Med. 2009 Dec 15;5(1):27.
25. Major TW, Carey JP, Nobes DS, Major PW. Orthodontic Bracket Manufacturing Tolerances and Dimensional Differences between Select Self-Ligating Brackets. J Dent Biomech. 2010 Jun 27;2010:781321
26. Joch A, Pichelmayer M, Weiland F. Bracket slot and archwire dimensions: manufacturing precision and third order clearance. Journal of orthodontics. 2010 Dec 1;37(4):241-9.
27. Arreghini A, Lombardo L, Mollica F, Siciliani G. Torque expression capacity of 0.018 and 0.022 bracket slots by changing archwire material and cross section. Prog Orthod. 2014 Dec 1;15(1):53.
28. Dolci GS, Spohr AM, Zimmer ER, Marchioro EM. Assessment of the dimensions and surface characteristics of orthodontic wires and bracket slots. Dental Press J Orthod. 2013 Apr;18(2):69-75.

29. Díaz RD, Díaz RR, Botello GR, Olvera SP. Tolerance in a 0.022" x 0.025" bracket slot from three commercial brands used in the Department of Orthodontics of the National Autonomous University of Mexico. Revista Mexicana de Ortod. 2014 Sep 30;2(3): e188-91.
30. Ancona MA, Díaz RR, Rodríguez FM, Olvera SP. Variations in slot size of selfligating brackets. Revista Mexicana de Ortod. 2015 Dec 31;3(4):e224-7.
31. Dalstra M, Eriksen H, Bergamini C, Melsen B. Actual versus theoretical torsional play in conventional and self-ligating bracket systems. J orthod. 2015 Jun 1;42(2):103-13.
32. Lee Y, Lee DY, Kim YJ. Dimensional accuracy of ceramic self-ligating brackets and estimates of theoretical torsional play. Angle Orthod. 2016 Sep;86(5):804-9.
33. Radhakrishnan PD, Varma NS, Ajith VV. Assessment of bracket surface morphology and dimensional change Contemp. Clin. Dent. 2017 Jan;8(1):71.
34. Silver M, Griffin Jr AC, Azzopardi L, Masoud MI, Tokede O, Griffin III AC. Novel methods reveal that parallelism contributes to the functional vertical slot dimension in ceramic and metal brackets. Angle Orthod. 2018 Nov;88(6):812-8.
35. Lefebvre C, Saadaoui H, Olive JM, Renaudin S, Jordana F. Variability of slot size in orthodontic brackets. Clin. Exp. Dent. Res. 2019 Oct;5(5):528-33.