

A COMPARATIVE EVALUATION OF CHANGES IN CLIP OPENING RESISTANCE OF PASSIVE SELF LIGATING DAMON ULTIMA SL AND DAMON Q2 SL BRACKETS UNDER INTRAORAL CONDITIONS

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Abstract

Objective: The aim of this study was to evaluate, under intraoral conditions, the opening resistance of the clip mechanisms of two passive self-ligating bracket systems, Damon Q2 and Damon Ultima, to support reliable bracket selection in clinical practice. **Subjects and Methods:** The materials consisted of measurements obtained from passive self-ligating maxillary first premolar brackets used in the orthodontic treatment of 20 patients. The force required to open the clips of Damon™ Q2 SL and Damon™ Ultima SL brackets (Ormco Corporation, California, USA) was recorded in grams using a digital force gauge mounted on a custom-designed experimental setup. After the initial measurements, the brackets were bonded to the palatal surfaces of the maxillary first premolar teeth. The experimental apparatus consisted of two parallel black acrylic blocks, a step motor providing linear motion, a motor control unit, and a digital force gauge. A clip-opening mechanism was fixed to the stationary block, while the force gauge was attached to the movable block. Linear movement was generated at a constant speed of 5 mm/min. After three months of intraoral use, the brackets were deboned and the measurements were repeated. **Results:** The results demonstrated that the mean clip-opening force of the Damon Ultima bracket at baseline (T0) was significantly higher than that of the Damon Q2 bracket. Although no significant difference was observed between the two systems at T1, the magnitude of force change from T0 to T1 was significantly greater for the Damon Q2 bracket. **Conclusion:** Intraoral exposure significantly increased the clip-opening resistance of both bracket systems. Damon Ultima showed higher initial forces, while Damon Q2 exhibited greater changes over time. These differences may influence clinical bracket selection. Further studies are needed to evaluate long-term performance.

Keywords: Self-Ligating Bracket, Damon, Slide-Open[®] Force, Intraoral Environment.

INTRODUCTION

In recent years, scientific and technological advances in orthodontics have led to substantial changes in both treatment approaches and the materials used [1]. In particular, bracket systems employed in fixed orthodontic therapy have continuously evolved with the goals of improving patient comfort and reducing overall treatment duration [2]. Self-ligating brackets (clip/slide brackets; SLBs), developed in the mid-1930s, have produced significant changes in orthodontics. These brackets eliminated the need for an external

ligature to retain the archwire and thereby facilitated wire changes and reduced chair time [3].

The clinical advantages attributed to self-ligating systems have been pivotal in their widespread adoption in orthodontic practice. Several studies have suggested that these systems may shorten treatment time and extend intervals between follow-up visits. These potential benefits have been linked to faster and easier archwire changes and to increased biomechanical efficiency resulting from lower frictional forces. However, there is no complete consensus regarding whether these advantages can be generalized to all cases, and outcomes appear to vary according to patient-related factors [4].

Self-ligating bracket systems that can be closed without the use of ligatures are reported to offer notable advantages over conventional bracket systems in maintaining oral hygiene and enhancing patient comfort [5]. It has been reported that adverse effects such as increased plaque accumulation and soft-tissue irritation associated with ligature use are reduced in these systems [6]. Mechanical irritation and related pain have also been described at lower levels. These characteristics have been reported to improve patient cooperation during prolonged treatments and to positively influence overall patient satisfaction[7]. Moreover, studies have demonstrated that frictional forces between the archwire and bracket are lower in self-ligating systems compared with conventional systems[8].

In vitro investigations have indicated that self-ligating systems not only reduce frictional forces but may also exert favorable effects on torque control. Nevertheless, variable factors such as the fit between the archwire and bracket slot, as well as archwire diameter, have been emphasized as important determinants of frictional behavior [9].

In the study conducted by Pizzoni, passive self-ligating brackets from different manufacturers were compared with conventional bracket systems, and a significant reduction in frictional forces between the archwire and bracket was reported. In these systems, frictional resistance was attributed to be lower due to structural features that allow freer movement of the archwire within the bracket [10]. In orthodontic treatment, reduced friction enables more effective force transmission and may facilitate faster tooth movement. These findings support the biomechanical advantages attributed to passive self-ligating bracket systems [11].

The first self-ligating bracket developed as an alternative to conventional bracket systems was the “Russell Lock” appliance introduced by Stolzenberg in 1935. This system, which offered an innovative approach to orthodontic treatment, attracted clinicians’ attention at the time of its introduction. The Russell Lock enabled rapid and practical placement of the archwire into the bracket via a mechanical clip, thereby simplifying the clinical procedure. This feature has been recognized as one of the principal advantages of self-ligating brackets [7]. The Damon bracket system, introduced by Dr. Dwight Damon in 1996, has played an important role in the development of passive self-ligating bracket technology in orthodontics. The system proposed an approach distinct from conventional fixed appliance therapy. Unlike conventional brackets, Damon brackets allow the archwire to

be engaged by a mechanically functioning slide/clip without the need for elastic or metal ligatures [12]. Accordingly, reduction of frictional forces is targeted and the application of light, physiologically and biologically compatible forces during treatment is facilitated. Thus, treatment is intended to proceed in a more comfortable and efficient manner [13]. Today, the Damon system is widely preferred worldwide and has become one of the fundamental approaches in modern orthodontics, based on the advantages it claims to offer for both clinicians and patients [14, 15].

The aim of this study was to comparatively evaluate, under intraoral conditions, the opening resistance of the clip mechanisms of two passive self-ligating bracket systems marketed as Damon Q2 and Damon Ultima. By measuring the clip-opening forces encountered during clinical use, this study aimed to provide scientific data to support more reliable bracket selection for orthodontists in clinical practice.

METHOD

This clinical study was designed as a prospective comparative analysis. Ethical approval was granted by the Istanbul Okan University Ethics Committee (Decision No: 183, Date: 11.12.2024). All participants provided written informed consent prior to enrolment.

The passive self-ligating brackets used in this study were maxillary first premolar brackets of Damon™ Q2 SL (Ormco Corporation, California, USA) and Damon™ Ultima SL (Ormco Corporation, California, USA). The brackets were used in the orthodontic treatment of 20 patients receiving fixed appliance therapy at the Department of Orthodontics, Faculty of Dentistry, Istanbul Okan University. In each patient, one bracket of each type was bonded for use as a button. For statistical comparison, the force required to open the bracket clip was recorded in grams using a digital force gauge (Lyman, Virginia, USA) mounted on the experimental setup, and these measurements constituted the study data. Damon Q2 SL and Damon Ultima SL brackets are shown in Figure 1.



(a)

(b)

Figure 1: a) Damon Q2 SL b) Damon Ultima SL

In patients whose fixed orthodontic treatment continued at the Faculty of Dentistry, Istanbul Okan University, American Orthodontics Mini Master MBT brackets with 0.022 × 0.025-inch slots were used. In participants who consented to the study, passive self-ligating Damon™ Q2 SL and Damon™ Ultima SL brackets were bonded, one each, to the palatal surfaces of the maxillary premolars numbered 14 and 24. Slot appearances under magnification are shown in Figure 2 for Damon Q2 SL ('torque in base') and Damon Ultima SL ('torque in slot') brackets.



Figure 2: Slot appearances under magnification

a) Damon Q2 SL, 'Torque in base' b) Damon Ultima SL 'Torque in slot'

Bonding Procedure

Bonding procedures were performed in accordance with the manufacturers' recommendations. The palatal surfaces of the maxillary premolars were etched with 37% phosphoric acid for 30 seconds, after which Tokuyama Bond II (Tokuyama Dental Corporation, Tokyo, Japan) was applied and air-dried for 5 seconds. Polymerization was then performed for 3 seconds using a Valo LED curing unit (Ultradent, Utah, USA). Bracepaste adhesive (American Orthodontics, Wisconsin, USA) was applied to the bracket bases, and excess adhesive was removed from around the clip mechanism with an explorer. Final curing was completed using the Valo LED unit for 3 seconds per surface at an irradiance of 1400 mW/cm².

Stepper Motors

Stepper motors are systems that convert electrical energy into mechanical energy through rotational motion. Because they operate in discrete angular increments, they are also referred to in the literature as "step motors." Pulse signals applied to the input terminals cause the rotor to perform a controlled, incremental rotational motion. These motors have a permanent-magnet pole structure that enables high-precision positioning. The operating principle is based on the interaction between the magnetic field generated

by the stator and the magnetic field on the rotor. Accordingly, the rotor moves by the predefined step angle in response to successive excitations. The operating principle of the stepper motor is shown in Figure 3.

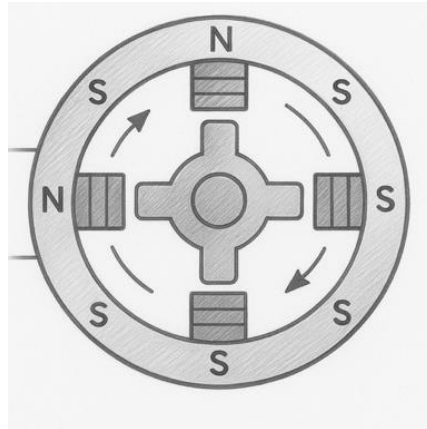


Figure 3: Operating principle of a stepper motor

The rotational speed of stepper motors varies depending on the applied voltage, signal frequency, and number of poles, allowing operation at different speeds and precision settings. Stepper motor performance is primarily determined by speed and torque parameters. Rotor speed is controlled by the frequency of the digital pulse signals applied to the inputs; increasing signal frequency increases motor speed, whereas decreasing it reduces speed. The direction of rotation can be controlled by changing the sequence of signal application. Speed is influenced not only by signal frequency but also by the step angle and structural characteristics of the motor; a smaller step angle increases positioning precision. Torque is a key parameter that reflects the load-carrying capacity of stepper motors, and three principal torque concepts are defined in the literature: holding torque, pull-in torque, and pull-out (drag) torque. Holding torque denotes the maximum moment by which an energized motor can maintain its position; pull-in torque denotes the highest moment the motor can generate at start-up; and pull-out torque denotes the maximum moment that leads to loss of synchronization during operation.

The relationship between speed and torque in stepper motors is described by a characteristic curve: higher torque can be obtained at low speeds, whereas torque decreases as speed increases. Therefore, the speed–torque curve is an important criterion for motor selection in applications requiring precise positioning. In this study, a Nema 17 stepper motor (NEMA, Virginia, USA) with a 1.8° step angle (200 steps/revolution), 12 V, 1.4 A, and 3.2 kg·cm torque was used to apply a pulling motion at a constant speed of 5 mm/min.

The Experimental Setup

The experimental setup consisted of two black acrylic blocks positioned parallel to each other and capable of sliding along a single axis, a stepper motor providing motion, a motor control unit, and a digital force measurement system. The apparatus was designed to

ensure controlled linear movement and to precisely record the forces applied during bracket clip opening. A custom mechanism for opening the clip of passive self-ligating brackets was mounted on the stationary acrylic block, while the digital force gauge was mounted on the movable block. By transferring the linear motion generated by the stepper motor to the force gauge, the forces required to open the bracket clip were measured at a constant speed of 5 mm/min. The digital force gauge was connected to an arm positioned perpendicular to the motion axis of the apparatus. The rotary motion of the Nema 17 stepper motor was converted into linear motion via a sliding mechanism and transmitted to the arm of the force gauge, thereby applying a direct tensile force to the bracket clip mechanism. The clip-opening system comprised a vertical arm applying force to the clip, a custom slot to stabilize the bracket, and a coupling unit to transmit force. The bracket slot was designed using CAD/CAM, considering the similar base geometries of Damon™ Q2 SL and Damon™ Ultima SL premolar brackets, and was manufactured on a metal block using CNC milling. This ensured stable fixation of the brackets during testing. During the experiment, the force was generated by the Nema 17 stepper motor controlled via Arduino IDE software and was transmitted to the bracket clip in a controlled manner. All measurements were performed in a dry environment at room temperature. Force was increased gradually until the first movement of the clip mechanism was observed; this value was recorded as the “clip-opening force.” The highest value recorded during opening was defined as the “maximum resistance force.” This protocol enabled comparison of the opening dynamics of different passive self-ligating bracket systems under standardized and reproducible conditions. The experimental setup is shown in Figure 4 and the opening of the bracket clip in the experimental setup is shown in Figure 5.

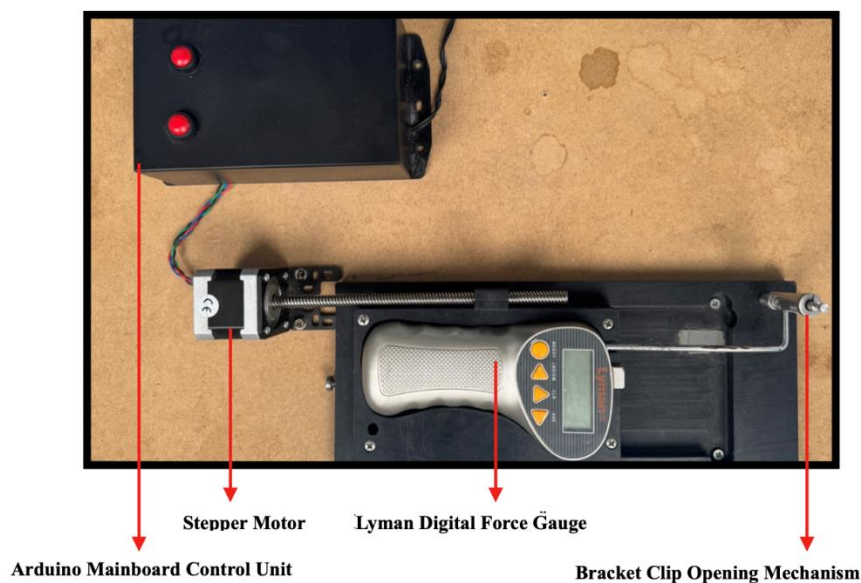


Figure 4: Experimental Setup

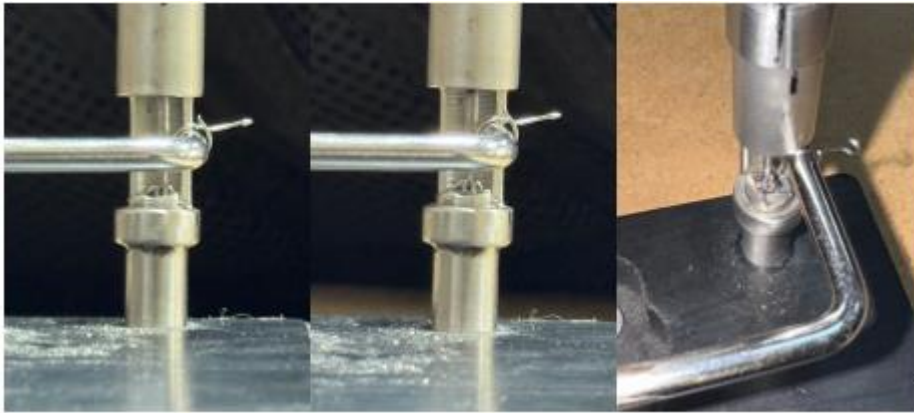


Figure 5: Opening of the bracket clip in the experimental setup

Debonding Procedure

Twelve weeks after bonding, the passive self-ligating brackets were removed using a lingual bracket debonding plier without opening the clip mechanisms. Following debonding, residual adhesive on the tooth surfaces was removed using tungsten carbide burs, and the enamel surfaces were polished with rubber points to complete the procedure. Debris images under magnification for Damon Q2 SL and Damon Ultima SL brackets are shown in Figure 6.

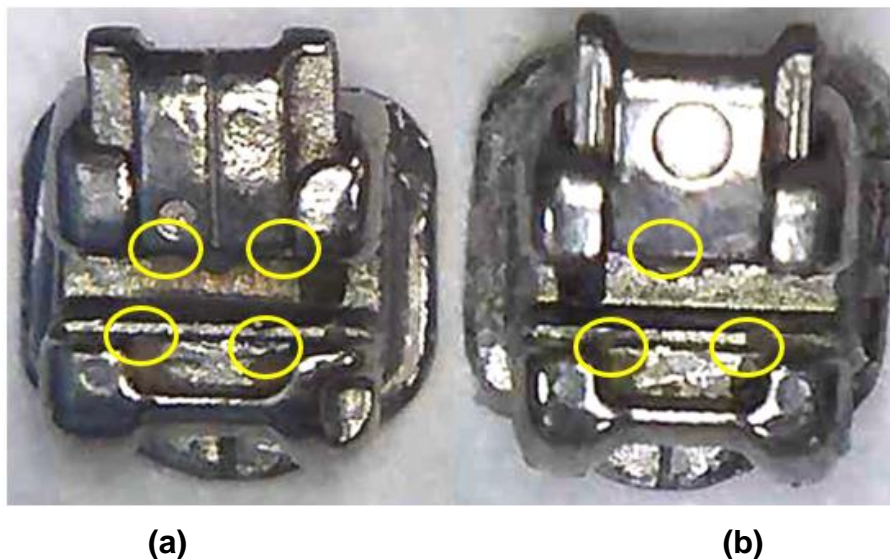


Figure 6: Debris images under magnification: (a) Damon Q2 SL, (b) Damon Ultima SL

Statistical Analysis

For evaluation of the study outcomes, IBM SPSS Statistics 27 was used for statistical analysis. Normality of the parameters was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. For between-group comparisons, Student’s t-test was used for

normally distributed parameters and the Mann–Whitney U test for non-normally distributed parameters. For within-group comparisons of normally distributed parameters, the paired-samples t-test was used. Statistical significance was set at $p < 0.05$.

RESULTS

In this study, 20 Damon Q2 and 20 Damon Ultima passive self-ligating maxillary premolar brackets were used. Clip-opening force measurements obtained prior to bonding were recorded as T0, and measurements obtained after debonding 12 weeks after bonding were recorded as T1. Bracket clip opening forces within and between groups are presented in Table 1.

Table 1: Assessment of bracket clip opening forces within and between groups

Bracket clip opening forces	Damon Q2	Damon Ultima	¹ p
	M±SD	M±SD	
T0	475,89±138,82	572,29±148,26	0,040*
T1	683,31±177,58	665,77±129,89	0,723
² p	0,001*	0,033*	

¹Student t test, ²Paired samples t test, * $p < 0.05$

The mean clip-opening force of the Damon Ultima bracket at T0 was significantly higher than that of the Damon Q2 bracket ($p = 0.040$; $p < 0.05$).

There was no statistically significant difference between the brackets in mean clip-opening force at T1 ($p > 0.05$).

In the Damon Q2 bracket, the increase observed at T1 relative to the mean clip-opening force at T0 was statistically significant ($p = 0.001$; $p < 0.05$).

In the Damon Ultima bracket, the increase observed at T1 relative to the mean clip-opening force at T0 was statistically significant ($p = 0.033$; $p < 0.05$).

The magnitude of force change from T0 to T1 in the Damon Q2 bracket was significantly greater than that observed in the Damon Ultima bracket ($p = 0.045$; $p < 0.05$).

Changes in force magnitude in T1 measurements are presented in Table 2 and changes in the forces required to open bracket clips are shown in Figure 7.

Table 2: Assessment of changes in force magnitude in T1 measurements

Bracket	Change in Force			
	M±SD	Median	Minimum	Maximum
Damon Q2	207,42±223,74	244,765	-231,21	505,95
Damon Ultima	93,49±181,41	100,695	-254,02	534,17
p	0,045*			

Mann Whitney U test, * $p < 0.05$

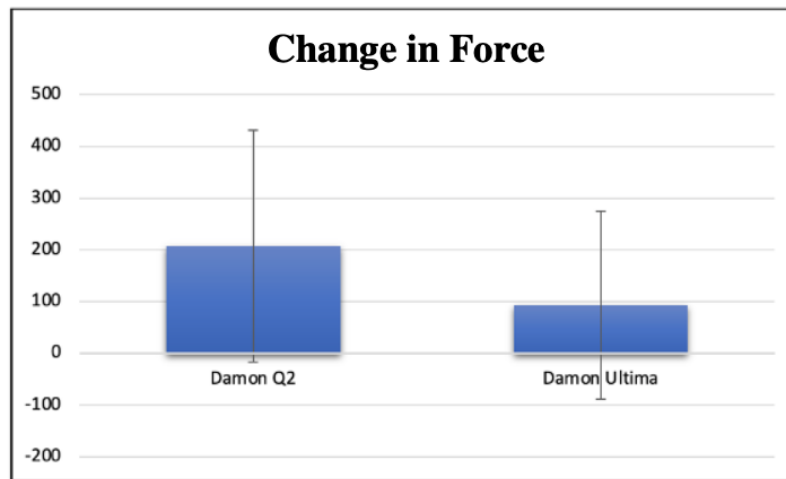


Figure 7: Changes in the forces required to open bracket clips

Reliability of the method

Based on the procedure described in a study by Dinesh and colleagues using a similar measurement method, a comparable experimental design was implemented to assess measurement reliability. In this context, four-link segments were cut from Ormco Closed Elastic Chain (Ormco, California, USA), stretched at a constant speed up to 10 mm, and the resulting tensile forces were measured and recorded. Measurements were performed using the experimental setup equipped with the Lyman Digital Force Gauge. In addition, data obtained from repeated measurements performed under identical experimental conditions using the M500-30CT Universal Testing Machine in the Materials Laboratory of the Faculty of Natural and Engineering Sciences, Istanbul Okan University, were compared independently using statistical methods.

At 1 mm, 2 mm, 5 mm, and 10 mm elongations, no statistically significant difference was found in mean force values between the digital force gauge and the universal testing machine ($p > 0.05$)

Self-ligating bracket systems have been investigated for many years with the aim of increasing the effectiveness of orthodontic treatment and simplifying clinical procedures. Orthodontists have examined the potential advantages of self-ligating mechanisms in an effort to mitigate the negative effects of conventional ligature-based systems on frictional resistance, hygiene, and treatment duration.

DISCUSSION

Self-ligating bracket systems have been the subject of research for many years with the aim of improving the efficiency of orthodontic treatment and simplifying clinical procedures [16]. Orthodontists have investigated the potential advantages of self-ligating mechanisms in an effort to reduce the negative effects of conventional ligated systems on frictional resistance, oral hygiene, and treatment duration [17].

Prettyman and colleagues evaluated orthodontists' clinical perceptions of self-ligating and conventional bracket systems, their reasons for preference, and beliefs regarding treatment effectiveness. A substantial proportion of participating orthodontists reported that self-ligating brackets reduce chair time, facilitate oral hygiene, and improve patient comfort. However, some clinicians indicated that these systems do not meaningfully shorten treatment duration and do not provide a clear superiority over conventional brackets in terms of final dental outcomes [18].

In a study conducted by Eberting, Straja, and Tuncay, the clinical performance of the Damon self-ligating bracket system and conventional ligature-based brackets was compared. Cases treated by different clinicians were examined, and treatment duration, number of follow-up visits, and quality of treatment outcomes were assessed. According to the findings, mean treatment duration was approximately 6–7 months shorter in cases treated with the Damon system, and approximately seven fewer follow-up appointments were required [19].

Another reason cited for preferring self-ligating brackets is the claim that their performance is less affected by friction between the archwire and bracket slot. Numerous studies have addressed this issue [20]. Ehsani and colleagues reported that self-ligating brackets exhibit lower friction values than conventional brackets in an ideally aligned arch [21]. In an in vitro study by Stefanos and colleagues comparing active and passive self-ligating systems, passive self-ligating brackets demonstrated lower friction than active self-ligating systems under sliding mechanics with a 0.019 × 0.025-inch stainless-steel wire [22].

Despite their perceived benefits, orthodontists have also encountered certain drawbacks as they have continued to use self-ligating bracket systems[18]. Deformation of the clip mechanism components or loss of function has been reported as an important technical challenge in clinical practice [23].

Harradine evaluated the long-term clinical performance of self-ligating brackets and reported, among patients treated with the Damon system, a total of 31 clip fractures and 11 instances of unintended clip opening during the treatment period [24].

In a recent study by Nalabothu and colleagues using passive self-ligating lingual brackets, repeated opening and closing was reported to reduce clinical performance, and mechanical failures were described [25]. Carneiro and colleagues, after opening and closing self-ligating brackets 500 times, identified significant plastic deformation and loss of stiffness [26].

Damon brackets are frequently used by orthodontists [27]. Ultima was selected because it is the newest model of the series, whereas Q2 was selected because it has been used for a long time and remains popular among clinicians. In this study, we aimed to evaluate changes in the clip mechanisms of two different self-ligating brackets after intraoral exposure. To this end, changes in clip-opening forces were used as an indicator. Pandis and colleagues investigated intraoral changes in self-ligating brackets and reported

deterioration of clip mechanisms and loss of stiffness in brackets exposed to intraoral conditions for longer than 15 months [28].

Changes in frictional forces of conventional and self-ligating brackets in wet environments have been investigated in various studies. Pratten and colleagues examined the effect of saliva on friction in metal and ceramic brackets and reported that saliva increases friction [29]. Araujo observed increases in frictional forces after saliva exposure in both conventional and self-ligating brackets and reported that this increase was greater in self-ligating brackets. In contrast, Reicheneder found no significant change and emphasized that the effect of wetness depends on the bracket model, wire, and protocol [30].

Based on information obtained from the manufacturer, no marked differences were identified between the metal content, clip mechanism designs, and dimensions of the brackets used in this study. No prior study directly comparing these two brackets was identified in the literature. The most evident difference between the two brackets was observed in the slot and base designs. Park and colleagues compared debris accumulation among different brackets after intraoral exposure and suggested that slot shape may influence the amount of accumulated debris [31]. Moolya investigated the effects of different bracket designs on plaque and microbial load and reported that slot and wing geometry play a determining role in plaque accumulation, arguing that bracket morphology is an important factor in debris accumulation [32].

In this study, the bonded brackets were retained intraorally for 12 weeks in order to investigate early clinical changes in self-ligating brackets. Studies have shown that during the first months of intraoral use, debris accumulation and mechanical wear can lead to alterations in the mechanical behavior of the ligation mechanism [33]. Araujo and colleagues retained brackets intraorally for 8 weeks to investigate early changes [34]. Longer-term studies are also available; in the study by Pandis and colleagues, brackets were retained intraorally for 19 months to investigate material wear and metal fatigue associated with long-term use [7].

In our study, both passive self-ligating bracket systems exhibited a statistically significant increase in resistance against clip opening after 12 weeks of intraoral exposure, and the magnitude of these increases differed significantly between the two brackets.

Before intraoral placement, the mean minimum force required to open the Damon Ultima passive self-ligating maxillary premolar bracket in vitro was 572.29 ± 148.26 g.

Before intraoral placement, the mean minimum force required to open the Damon Q2 passive self-ligating maxillary premolar bracket in vitro was 475.89 ± 138.82 g.

In a study by Gandini comparing clip-opening resistance among different self-ligating bracket models and including Damon Q passive self-ligating brackets, it was reported that forces of 4.89 N (498.6 g) for the maxillary central incisor bracket and 2.81 N (286.5 g) for the mandibular incisor bracket were required to open the clips [35]. In that investigation by Gandini and colleagues, it was reported that the forces required to open passive self-ligating brackets produced by different manufacturers varied, and that even within the

same brand, brackets designed for different tooth positions exhibited different opening resistances. The clip-opening force values obtained in the present study are comparable to the ranges reported by Gandini and colleagues.

Aside from the studies by Carneiro and Gandini, no study similar to ours that reports clip-opening forces could be identified in the literature.

Manufacturers provide different recommendations for opening the clips of self-ligating bracket models. The Damon system incorporates a specific opening–closing geometry termed SpinTek. Rather than relying on a unidirectional force, this mechanism is designed to distribute opposing forces, which Ormco states reduces the total force required by the clinician and enables more controlled and balanced opening. Technical documentation indicates that forces up to approximately 1.3 kg may be required to open the clip; however, the SpinTek geometry is stated to reduce this value [36].

In the present study, a unidirectional force was applied and a system-specific opening key was not used. No other study evaluating changes in clip-opening forces of Damon systems was identified in the literature.

In their review of studies on self-ligating brackets, Chen and colleagues stated that the technological advantages claimed are not consistently associated with clinically meaningful differences across studies [37]. The authors emphasized the need for high-quality, standardized, long-term follow-up studies to substantiate the potential advantages of self-ligating systems [38].

CONCLUSION

In two different self-ligating bracket systems exposed to intraoral conditions for 12 weeks, resistance to clip opening increased significantly in both systems. Initial in vitro measurements indicated that Damon Ultima brackets exhibited higher opening resistance than Damon Q2 brackets; however, after intraoral exposure, the increase in resistance observed in Damon Ultima brackets was significantly lower. These findings indicate that frictional behavior is influenced by intraoral conditions and that intraoral exposure induces meaningful changes in clip mechanisms. Furthermore, the custom experimental apparatus provided sufficient reliability and reproducibility for measuring orthodontic forces, enabling stable and comparable acquisition of mechanical data..

Recommendations

- Measuring clip-opening forces in both bracket systems may guide orthodontists in clinical practice.
- The superior intraoral performance observed for the Damon Ultima bracket represents a clinically noteworthy finding.
- Increasing the number of studies focusing on clip mechanisms of self-ligating brackets may contribute to a more robust evaluation of their clinical success.

Conflict of Interest

The authors declare that they have no conflict of interest.

Data Availability

All data generated or analyzed during this study are included in this published article.

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