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Comparison of the Frictional Force Between Single and Double Slot Conventional Bracket Double Wire Technique: An In- Vitro Study

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Abstract
The movement of one object tangentially against another generates friction, which is also true for orthodontic brackets sliding along the arch wire. Friction plays a crucial role in orthodontics because it creates resistance to movement as the bracket slides along the wire. This resistance can slow down the movement of the wire and transfer excessive forces to the posterior anchor teeth, causing loss of anchorage. Therefore, efforts should be made to minimize frictional forces when planning orthodontic tooth movement. Sliding mechanics is widely used in orthodontics, and the evolution of bracket systems is evidence of its importance and popularity. Different bracket systems have been developed to address the problem of malocclusion, with each new iteration bringing improvements to treatment. However, frictional resistance remains a concern when utilizing sliding mechanics in orthodontics.
The purpose of the study is to compare the frictional force generated by arch wires in two different types of orthodontic brackets: the single slot conventional bracket and the newly introduced double slot bracket. The single slot conventional bracket is available in either 0.018 or 0.022 slot sizes, while the double slot bracket has a single bracket with both 0.018 and 0.022 slots. In the study, both types of brackets will be tested together using arch wires. The aim is to determine if the double slot bracket design reduces frictional resistance compared to the single slot conventional bracket, and if so, by how much. The results of the study could provide valuable insights into the effectiveness of the double slot bracket in reducing friction and improving orthodontic treatment outcomes.
Methodology: The arch wire-bracket assembly ligated by a ligature wire mounted in an acrylic base samples divided into two groups Set A – Single Slot Brackets and Set B – Double Slot Brackets were each tested for friction by pulling together the arch wires 0.016 x 0.022 SS and 0.016 Niti gripped by a crimping brass fittings on one end and the other grip is holding the arch wire-bracket assembly. The load cell registered the force levels required to move the wire along the three aligned brackets; these levels then were transmitted to a computer hard disk. The arch wires moved at a crosshead speed of 1.0 mm/6 sec. Load values of FR were calculated in Newton (N).
Conclusion: The study's findings show that there is no significant difference in the frictional forces generated by arch wires between the single slot and double slot brackets. This means that both types of brackets can be used interchangeably for orthodontic treatment. For example, in cases where there is an infra-erupted tooth or a palatally located tooth, either bracket system can be used with confidence since they both provide similar levels of resistance to the movement of the arch wire. This is an important consideration in orthodontic treatment as it ensures that the desired tooth movement is achieved efficiently

and effectively. Overall, the study's results provide valuable information for orthodontic practitioners when selecting the appropriate bracket system for their patients.

Keywords: single slot brackets, double slot brackets, frictional force, bracket system, archwires

Chapter I
The Problem and Its Background
Introduction

When an object moves tangentially against another, friction is created. As orthodontic brackets slide along the arch wire, friction (static or kinetic) is generated. Friction is a small but significant component of the resistance to movement as the bracket moves along the archwire (Singh, 2014).

Orthodontic brackets transfer the forces of the arch and appliances to the teeth. In orthodontics, when the sliding mechanics are used to close the gap to retract a single tooth or a segment of teeth, a distally directed force pulls the anterior teeth back as an arch wire slides through the brackets and tubes in the buccal segments. The resulting frictional force can create significant resistance to movement. This force slows the movement of the arch wire through the bracket slots as the anterior teeth are retracted, and can additionally transfer excessive forces to the posterior anchor teeth, resulting in loss of anchorage. Thus, when orthodontic tooth movement is planned, frictional forces should be considered and efforts should be made to minimize them.

Sliding mechanics is widely use in Orthodontics and commonly seen in Orthodontic biomechanics. The evolution of Bracket System is evidence of its importance and popularity. Researchers, Inventors and different companies undeniably go through the tedious research process and testing to come up and manufacture the best materials readily available for every Orthodontic Practitioner.

The innovation of different bracket systems brought a new approach to the treatment of the different problems of malocclusion. From the original edgewise bracket to the conventional straight wire system, later modified self-ligating bracket system and up to the latest modification which brought the conventional double slot bracket system. As the sliding mechanics is being utilized, problems such as friction resistance are always of concern. In edgewise and straight-wire brackets, the main mechanism is the rectangular slots and their interaction with the arch wires (Pizzoni, 1998).

The evolution of bracket design began with the ancestral structure of the vertically positioned slot in the ribbon arch appliance and progressed to the pure rectangular horizontal slot in the traditional standard edgewise to the contemporary pre-adjusted brackets in the straight wire technique, and finally to the modern pre-adjusted brackets in the straight wire technique and to the current self-ligating brackets system design (McManaman & Woodside, 2000; Katsaros & Dijkman, 2003).

A single slot bracket would either be a slot 0.022" wherein more freedom of movement of initial aligning arch wires in the relatively larger slot, or a slot 0.018" which claims of a better torque control and expression particularly in the anterior teeth (Samawi, 2014).

Double slot brackets originally started in 2009, when two instructors had a brilliant idea during a relaxed conversation during a class break: to convert a closed auxiliary slot into a second open slot located in the center of the bracket body. This audacious idea became the primary goal in order to make it a reality, resulting in significant benefits for their treatments and students (Sortech Ortodontia – Sortech Ortodontia, n.d.)

Double slot brackets design features both a slot 0.018 and 0.022 horizontal slots which can be used simultaneously or stand-alone depending on the biomechanics being utilized.
It is worth noting that, despite the numerous bracket designs, one feature has remained constant: there is a horizontal slot on the bracket's facial facet. In some design variations, such as the Tip Edge Plus, In-Ovation, and 'R' brackets, an additional horizontal slot is enclosed within the bracket base and is not open to the labial surface, allowing only segmental auxiliary arch wire engagement (Parkhouse, 2007).
A continuous arch wire system is simple to use and relatively comfortable for the patient; however, because the wire is inserted into a series of brackets, it is statically indeterminate. As a result, the forces generated by the appliance, as well as the forces resulting from function and muscular matrices, are unpredictable. Although a continuous arch wire can often produce satisfactory results, it can also cause unfavorable side effects, particularly in cases of significant individual tooth misalignment.
Using two wires simultaneously can help to reduce these side effects and thus improve the effectiveness of continuous arch wire systems. The approach is commonly referred to as "double wire technique." A stiffer wire, known as the "master," is used to control the arch form, and a highly elastic wire, known as the "server," is used to deliver the forces required for tooth alignment (Verna et al., 2005).
The purpose of these study is to compare the frictional resistance making use of 0.016 x 0.022 Stainless Steel Wire and 0.016 Niti wire between single slot conventional bracket which can either be with slot 0.018 or slot 0.022 with that of a newly introduced double slot bracket system wherein it is a bracket designed that features both 0.018 and 0.022 horizontal slot in a bracket. The study will make use of the double wire technique wherein 2 arch wires such as 0.016 x 0.022 Stainless Steel wire used as a base wire engaged in the bracket slot having a 0.016 NITI wire on top of it also engaged in the bracket slot. When movement of the dentition commence, the bracket and the wires interact during this movement creates friction especially observable in sliding mechanics where the wires slide through the bracket slots as the teeth move. In this aspect of time of treatment can we test if there's any difference between the single slot and double slot bracket using the 0.016 x 0.022 SS and 0.016 NITI wires.

Statement of The Problem

These study aims to compare the frictional force of arch wires between single slot conventional bracket and a newly introduced double slot bracket. Single slot conventional bracket can either be available in 0.018 and 0.022 slot respectively, while in double slot bracket, a single bracket having both 0.018 and 0.022 slots. The wires will be tested together.
Specifically, it will seek to answer the following questions:

1. What is the frictional force of .016 x .022 SS and .016 Niti using Single slot bracket?
2. What is the frictional force of .016 x .022 SS and .016 Niti using Double slot bracket?
3. Is there a difference in the frictional forces of Single slot and Double slot brackets in double wire technique?

Significance of the study:

The purpose of study is to perceive the viable advantage of double slot bracket invention in treatment, upgrade biomechanics and additional information about the bracket system highly significant and beneficial to the following:
Orthodontic Patients: To offer patients with prompt, efficient, and high-quality care while maintaining high levels of comfort. Modern metal braces are more modest than ever, providing patients with an

additional level of subtlety. These innovative designs provide outcomes in substantially quicker timeframes than their older equivalents. And, as our understanding of chemistry and biology has advanced, metal braces are now constructed of 100% stainless steel, which is non-toxic when compared to some materials utilized in the past.

Orthodontist: To provide a more thorough and in-depth comparison of the advantages of the usage of 0.018 and 0.022 slots in brackets especially if both slots are found in a bracket system and help in decision making on whether a conventional type or the double slot bracket system is better in treatment of certain cases wherein frictional resistance is widely observe.

Future Researchers: Provide a reference for future study about the newly invented double slot bracket system and its effectivity in treatment and resistance to friction.

Dental Students: A reference in the different bracket system available and innovations as part of their learning with orthodontic materials and appliances and may help in them in choosing which bracket system is suitable for their future cases and use. To have in-depth understanding of characteristics of orthodontic appliance and factors determining friction resistance when in use.

Clinical Instructors/ Professors: Help in the formulation and/or modification of biomechanics in treatment.

Conceptual Framework:

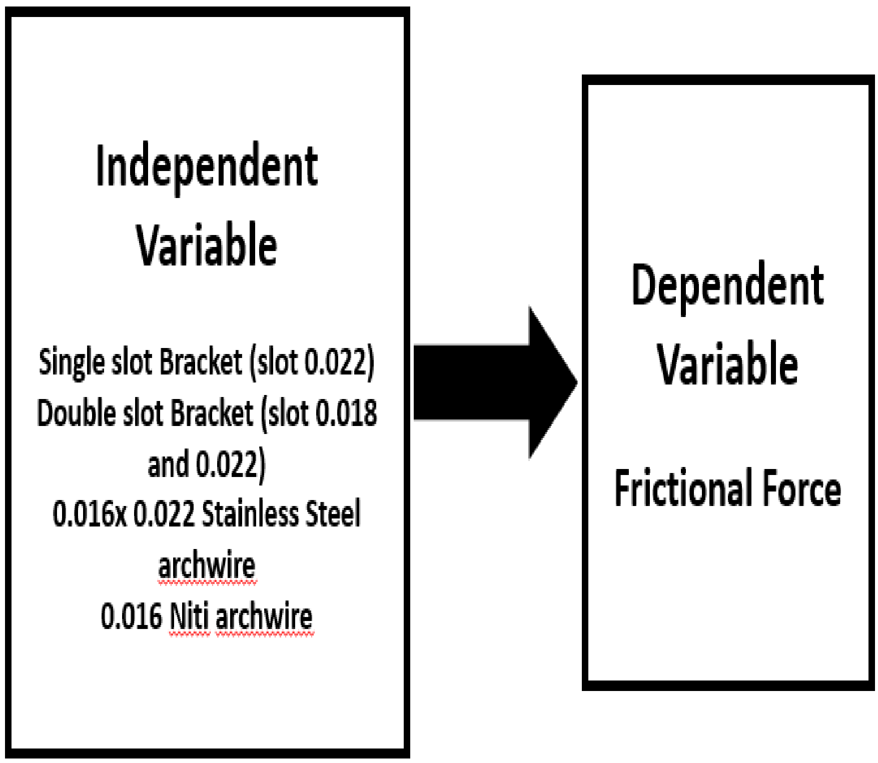

Figure 1: Paradigm of the Study

Comparison of The Frictional Force Between Single and Double Slot Conventional Bracket Double Wire Technique: An In- Vitro Study

Hypothesis:

H01: There is no significant difference in Frictional forces of arch wires between a single slot and a double slot bracket.

Scope and Limitation of the Study

The Double slot bracket is a recently designed bracket system that combines slots 0.018" and 0.022" in one bracket; hence, no studies or publications have been conducted or published on the bracket system. Two arch wires will be utilized in particularly 0.016 x 0.022 SS as the base wire and 0.016 NIti as the overlay wire. A slot 0.022 metal stainless steel brackets making use of the upper canine, 1st premolar and 2nd premolar respectively ligated making use of 0.010" ligature wire will be used in the study. A friction force test will be done making use of a Universal Testing machine at the Construction and Materials Laboratory, Engineering Department, University of the Philippines – Diliman, Quezon City, Manila

Inclusion Criteria:

- Double slot bracket
- Single slot bracket
- Limited study on double slot bracket
- 0.016 x 0.022 SS wire/ 0.016 Niti
- Brackets to be use- upper canine/1st premolar/2nd premolar
- 15 sets of conventional single slot metal brackets
- 15 sets of double slot metal brackets

Exclusion Criteria:

- Defective Brackets
- Defective wires
- Wires that are not included in the study

Definition of Terms:

The following terms will be defined conceptually and operationally in this study.

Conventional Brackets - metal brackets bonded to the front of each tooth and anchored together with an arch wire (Conventional Metal Brackets | Braces in North Shore, n.d.)

Double slot Bracket – is a bracket system with two horizontal slots, one with a 0.018" slot and the other with a 0.022" slot.

Double Wire Technique – engagement of two wires on top of the other specifically used in cases where impaction is present or there is any observable palatally or lingually located or misaligned tooth that needs retraction into the line of occlusion. Mostly used in leveling and alignment stage

Frictional Force - a force that retards or resists the relative motion of two objects which are in contact (Bs et al., 2014).

Instron machine – it is a type of Universal Testing machine wherein in this study will be used to test the frictional force of the brackets and arch wire interface

Niti wire - also known as nickel-titanium or Ni-Ti alloy, is commonly used in orthodontics thanks to its shape memory and super elastic behavior. We use arch wires made from this clever metal alloy to move teeth efficiently and reduce the frequency of adjustments.

Resistance – ability of a material to prevent or oppose to be affected.

Single slot bracket - is a bracket system having horizontal slot either slot 0.018" or 0.022".

Slot 0.018" – claims of improved torque control and expression, especially in anterior teeth, due to reduced movement between the 0.018" slot and the standard 0.016" x 0.022" or 0.017" x 0.025" finishing arch wires in the finishing steps. (Samawi, 2014)

Slot 0.022" - Bigger working arch wires, such as 0.019" x 0.025" SS, can perform better for space closure and overbite control due to higher flexibility of movement of initial aligning arch wires in the relatively larger slots. (Samawi, 2014)

Stainless Steel wire - Stainless steel archeries are stiff, have low springiness, are resistant to corrosion, have a low range and good formability. The wire is also often cheaper than the other arch wires and can be easily used as working arch wires in an orthodontic treatment plan

Chapter II

Review of Related Literature and Studies

This chapter discusses the relevant literature and studies from orthodontic sources. It includes various studies on brackets and arch wires, as well as various cases where double wire techniques were used and defined conceptually and operationally for comprehensibility. It also includes facts and information about the research problem, as well as explanations and logical connections between previous and current research.

Friction

Friction represents "The function of the relative roughness of two interacting surfaces and results when the two relative surfaces move against each other" (Vartolomei et al., 2022)

Kinds of friction are Static friction which is "The lowest force required to initiate orthodontic tooth movement when two surfaces are statically related", while kinetic friction equals "The force that resists the movement of one object against another when a constant speed is applied"

Static and kinetic friction exist if the wire is in a passive position, parallel to the bracket, but this is never observed in clinical settings. Tooth movement occurs when an applied force overcomes the friction at the bracket slot–arch wire contact point. Low forces, on the other hand, are chosen to protect anchorage and avoid a significant risk of root resorption and elevated levels of discomfort. Thus, it is important to acknowledge the friction between the bracket and arch wire in order to apply proper force levels to obtain adequate tooth movement and an optimum biological response.

Friction in Wires and Bracket

Frictional force occurs when two bodies in contact have relative motion or the potential for relative motion, and when the contacting surfaces are not perfectly smooth. The sliding frictional force is the component of the total contact force between the surfaces that is directed in the direction of the intended or actual sliding motion and opposes it. (Jakati, Vijayvargia, 2017)

Influence of Archwire and Bracket Dimensions On Sliding Mechanics

Friction (static or dynamic) in orthodontic tooth movement is the result of an arch wire's interaction with the sides of a brackets or ligature. Friction is only a small part of the resistance to movement when a bracket slides along an arch wire. Kusy and Whitley, classified resistance to sliding (RS) into three components: (1) static or kinetic friction (FR) caused by contact of the wire with bracket surfaces; (2) binding (BI) caused by contact between the wire and the corners of the bracket (when a force is applied to a bracket to move a tooth, the tooth tips in the direction of the force until the wire contacts the corners of

the bracket, and binding occurs); (3) notching (NO), when the wire undergoes permanent deformation at the wire-bracket corner interface.(Burrow, 2009)
Friction is thus a difficult entity that must be dealt with efficiently in order to achieve a favorable outcome. By reducing frictional resistance during retraction, the majority of applied force can be transferred to the teeth. As a result, orthodontic tooth movement is optimized while undesirable anchorage loss is reduced. (Jakati et al., 2017)

Variables that Affects Generating Friction

There are many influences affecting the source of how high or low a friction can be existent as mentioned by Al Subie & Talic (2016) and this includes bracket choice, wire placement and angulation, properties of arch wire and ligation system to name that greatly affects the outcome.
Variables such as bracket composition, bracket width, interbracket distance, slot size, arch wire type, arch wire size, second order angulation, degree of torsion, ligation, and whether the environment is wet or dry influence friction generated by an arch wire and bracket interaction.
Crincoli et al. (2013) investigated whether he following factors influence friction force values during alignment phase: degree of malalignment, orthodontic wire diameter, and bracket/ligature combination.
Sobouti et al., (2015) mentioned that a reduction in frictional resistance improves the response of both hard and soft tissues. "Studies have shown that approximately 50% of force required for movement of the teeth is used to overcome the frictional force. The type of bracket, physical properties, size, and alloy of arch wires, saliva, angulation of the wire to the bracket, method of ligation, contact angles, size and design of bracket slot", and method of wire-bracket ligation are all factors that affect frictional resistance.

Arch wires

Stainless Steel: Norris Taylor and George Paffenbarger proposed steel as a gold substitute at the AAO Conference in 1931. Archie Brusse, the founder of Rocky Mountain Orthodontics, proposed the clinical application of stainless steel
in orthodontics for the first time in 1933. Stainless steel was first used in the manufacture of orthodontic accessories in Brazil in the late 1940s. It is typically made from AISI (American Iron & Steel Institute) 302 & 304 alloys. 304 alloys are similar to 302 alloys except that they contain 0.8% carbon.
Composition includes Chromium -17-25%; Nickel - 8-25%; Carbon - 0.2%; Iron for balance
Gradations of Stainless Steel would be described as Regular grade wherein wires can be bent to almost any desired shape without breaking and that of Super grade which Yield strength is very high but is brittle thus it breaks when bent sharply.
According to American Orthodontics, they are categorized as Standard, Gold Tone and Super Gold Tone**.**
General properties of stainless steel wires include: great ductility, formability, ease of welding, ability to endure cold work without fracture, ability to overcome sensitization. Stainless steel advantages include low cost, biocompatibility, excellent formability, and the ability to be soldered and welded. Disadvantages of stainless steel includes High force delivery, relatively low spring back in bending compared to beta-titanium and Nickel titanium alloys, can be susceptible to inter-granular corrosion after heating to temperatures required for joining. (Shah, 2022)
Nickel Titanium Alloys: Unitek Corporation developed the NiTi alloy for clinical use under the brand name Nitinol® in 1972. The clinical and laboratory application of a novel super elastic nickel-titanium alloy was disclosed in 1985.

It was known as "Chinese Niti" until 1986, when "Japanese NiTi" was introduced. The GAC Company (GAC Int., NY, USA) manufactured these alloys under the trade name Sentalloy. The term "nitinol" refers to a class of nickel-titanium alloys that was developed by the Naval Ordnance Laboratory by Buehler and his colleagues**.**

Stabilized Niti Alloy, because wire processing provides a stable martensitic structure, these martensitic stabilized alloys lack shape memory and super elasticity. There are no alterations in the crystal structure.

Active Niti Alloy**,** has a fixed composition but is capable of changing its crystal structure when stressed or at a transition temperature.

Active Austenitic Alloy**,** the transformation temperature is lower than the room temperature. When stressed, the crystal structure changes from austenite to martensite. Active Martensitic Alloy, the transformation temperature is between room and oral temperature. When heated, it changes crystal structure from martensite to austenite.

Physical Properties of Niti: Shape memory: The capacity of a substance to recall its original shape after being physically distorted when in martensitic state. In a typical application, a certain form is created while the alloy is kept at a high temperature. Plastic deformation is possible when the alloy is cooled below the transition temperature. However, when heated sufficiently to regain austenitic structure, the original shape is restored. The wire returns to its original shape after being heated to a lower transition temperature. The cobalt content is used to control the lower transition temperature, which can be near mouth temperature 37°C (98.4° F). The cases that benefit the most from the use of nitinol wires are determined by the amount of tooth malalignment from the ideal arch form. The greater the deflection of the wire from the ideal arch shape when ligated into the bracket, the higher the advantage of nitinol wire over stainless steel. (Harini, 2020)

Brackets and its Evolution

Edward Angle proposed the 0.022-inch by 0.028-inch bracket slot size in 1925, which allowed better control of crown and root position with the precious metal arch wires available at the time. With technological advancements, stainless steel alloys began to be used in orthodontics, allowing for the production of thinner wires with the same stiffness as gold arch wires at a lower cost. This allowed for the reduction of bracket slot size to 0.018-inch. This did not, however, preclude the use of 0.022-inch bracket slots in clinical practice. (Vieira, 2019)

Conventional Brackets to Double Slot Brackets

Since its inception, the progress of orthodontics has seen notable events such as the advent of the Straight Wire Technique, the creation of various prescriptions, the use of slots of varying size, bone anchoring systems, and tomography, among others. Despite this, the styles and features given by the brackets were always the same and restricted. Great ideas have a long history, but they needed to be brought together in one piece. The invention of a novel bracket design with two central slots and each with distinct dimensions, one slot with dimensions of 0.018" X 0.030" and the other with dimensions of 0.022" X 0.028", now is a tool with multiple resources that generates significant benefits for professionals and patients and is gaining more and more followers every day. (Conventional Double Slot Orthodontic Bracket – Editora Plena, n.d.)

Double Wire Technique

Correction of certain malocclusions, such as a single tooth cross bite and a tooth placed palatally or lingually, frequently necessitates the use of a double wire NiTi arch wire attached to a stainless steel base arch wire. (Jain et al., 2016)

According to Sandler et al. (1999), the technique consists of a base arch wire which is usually stainless steel with high tensile strength and rigid to achieve and ensure maintenance of ideal arch form, also aids in preventing occurrence of any untoward distortions or rotations in horizontal or vertical plane that would be detrimental to whole orthodontic treatment process. The displaced teeth are then aligned using a nickel-titanium 'piggyback' arch wire with low flexural rigidity and high elastic recovery. Kim et al. (2007), stated that Double-arch wire mechanics was designed in such a way that the independent arch wire, a component of the double-arch wire mechanics, will enable a palatally or lingually located tooth to be retracted into occlusion without affecting other structures during tooth movement with the help of the base arch wire in place controlling adjacent tooth to be displaced. In instances of rotated tooth, the rotational forces have little effect on the abutment teeth when using this method. Traditionally, a smaller-sized main arch wire that is flexible enough to engage the rotated tooth is used. When rotational forces applied to the rotated tooth cause unwanted tooth movements in the abutment teeth, a series of wires is usually required to realign all of the teeth. The Piggyback Technique assists in avoiding waste of time and resources. (Alpern, 2012)

In the study by Frank and Nikolai in 1980, in cases of "canine retraction on a guiding arch wire, the amount of frictional resistance at a particular time/location in the over-all displacement is essentially independent of the position of the canine with respect to the lateral incisor and the premolar; When no second-order binding exists between wire and bracket, relative displacement will occur with the greatest ease when the ligature force and bracket/wire contact area are minimized; In the presence of binding angulations, such as occur in typical canine retraction mechanics on a continuous arch wire, computations combined with results of this investigation suggest that, with edgewise brackets, friction may be minimized by maximizing the contact area of the wire with the bracket slot, by maximizing wire bending stiffness, and by minimizing bracket width."

Chapter III
Methods and Materials

This chapter describes the research design selection process, description of samples, research instruments, data collection procedure, and Statistical analysis was utilized to solve the problems provided in Chapter I.

Research Design

The study made use of a Quasi-Experimental Design, which aims to establish a cause-and-effect relationship between an independent and dependent variable. A quasi-experiment does not rely on random assignment. Instead, subjects are assigned to groups based on non-random criteria as stated by Thomas, L. (2022). In this study, as the frictional resistance of 2 arch wires will be compared and tested in both 0.018 and 0.022 bracket slot.

Sample and Sampling Technique

The sampling method to be utilized in the study is purposive sampling, the process of selecting sample by taking subject that is not based on the level or area, but it is taken based on the specific purpose. Purposive sampling is where a researcher selects a sample based on the needs about the study, wherein fifteen sets of conventional brackets consisting of upper canine, first premolar and second premolar brackets respectively with slot 0.022 and fifteen sets of double slot brackets with both 0.018 and 0.022 slots were chosen specifically for this study to compare frictional force between the two brackets and are mounted on an acrylic block base with thickness of 30mm x 20 mm x 3 mm acrylic plate/block and brackets were bonded to the acrylic plate with epoxy resin. Arch wires 0.016 Niti and 0.016 x 0.022 SS are also selected. Low friction and conventional ligature wires are to be used to ligate arch wires to the bracket.

Research Instrument:

Each samples were mounted on an acrylic block base consisting of 2 sets. Set A with conventional brackets and Set B consisting of double slot brackets.

The following instruments and materials were used in the study:

1. For Acrylic Plates/Blocks, molded by using a box made up of pink wax or pvc foam board with thickness of 30mm x 20 mm x 3 mm acrylic plate. Trimmed excess acrylic and polished
2. Brackets bonded using cyanoacrylate adhesive (superglue/mighty bond/ epoxy resin) ,3 brackets (upper canine, 1st premolar, 2nd premolar) arranged in a row observing standard bracket distance for simulation, measured in mm by the use of metal or plastic ruler. Alignment of the brackets were obtained through the preliminary insertion of a 0.021 × 0.028″ SS arch wire into the slots of the brackets, without ligation, before bonding on the acrylic block.
3. Conventional Brackets –Set A
4. Double Slot Conventional Brackets – Set B
5. Ligature wire were used to tie the arch wire onto the bracket in a normal (straight tie) pattern.

Data Gathering Procedure

The test of the study adopted the methodology describe in the Published Article "Comparison of frictional resistance between various bracket types and arch wire materials ligated with low-friction and conventional elastic ligatures" of Sesham et al. (2015)

The brackets-wires specimen was arranged in thirty (30) sets as fifteen (15) sets for each group; 15 sets for group A, 15 sets for group B. The sets used a 60cm x 30cm x 20 mm acrylic plate. Each set have canine, 1st premolar and 2nd premolar brackets, Roth prescription metal brackets with slot size of 0.022 inches was used in all sets and were bonded to the acrylic plate using an epoxy resin.

For single slot set up (Group A), each acrylic plate was marked parallel to its long axis; these lines helped align the metal brackets. To ensure reproducibility of brackets alignment method, the method mentioned by Patil et al. (2016), whereby three metal brackets were supported by 0.021"x 0.028" stainless steel arch wire through the brackets slots with inter-bracket distance of 10 mm. The brackets were bonded to the acrylic plate by epoxy resin. The base wire for single slot bracket was .016 x .022 SS (60 mm) and the overlay is .016 Niti (60 mm). Both wires were engaged on the canine, 1st premolar and 2nd premolar brackets using .010' ligature wire. Ligature wires were twisted 9 times to ensure the uniformity of engagement.

For double slot set up (Group B), each acrylic plate was marked parallel to its long axis; these lines will help to align the metal brackets. To ensure reproducibility of brackets alignment method, the method mentioned by Patil et al. (2016), whereby three metal brackets were supported by 0.021"x 0.028" stainless steel arch wire through the brackets slots with inter-bracket distance of 10 mm. The brackets were bonded to the acrylic plate by epoxy resin. The base wire for double slot bracket was .016 x .022 SS (60 mm) and the overlay is .016 Niti (60 mm). .016 x .022 wires were engaged on the canine, 1st premolar and 2nd premolar brackets in the .022 slot of the double bracket using .010' ligature wire. The .016 Niti were engaged on the .018 slot of the double bracket using .010" ligature wire. Ligature wires were twisted 9 times to ensure the uniformity of engagement.

The wire-brackets combination specimens underwent friction test by subjecting each set (Group A and B) to a pulling force test to simulate sliding mechanics. Both arch wires were pulled together at the same time for 10mm (1mm/6secs) by Universal Testing Machine (UTM) (Instron 3366 series), a graph of applied forced were plotted on the monitor screen and were recorded in Newton Scale. This test necessitates the use of fixtures that allow for sliding motion, such as a sliding plane and a sled.

Statistical Analysis

Mean frictional forces of Single slot and Double slot brackets- Most commonly used to determine central position.

$$\bar{x} = \frac{\sum x}{n}$$

$$Mean = \frac{Sum\ of\ observations}{Number\ of\ observations}$$

Where:

x_i = mean

$\sum x_i$ = Sum of observations

N = Number of observations

Standard Deviation - A standard deviation (or) is a measure of how widely distributed the data is in reference to the mean. A low standard deviation suggests that Frictional force between single or double slot brackets is grouped around the mean, whereas a large standard deviation shows that Frictional force between single or double slot brackets is more spread out.

$$SD = \sqrt{\frac{\Sigma(x_i - \bar{x})^2}{n-1}}$$

Where:

X = the value in the data distribution

x = the sample Mean

n = Total number of observations

T test - A ***t* test** is a statistical test that is used to compare the means of two groups. The t-test formula is a statistical equation we use to determine if the difference between the mean (average) of two groups is big enough to be considered significant. It means that if we have the average values for two groups and they are significantly different, we can conclude that there is a considerable difference between the two groups

$$t = \frac{\overline{x} - \mu}{\frac{s}{\sqrt{n}}}$$

$$t = \frac{(\overline{x}_1 - \overline{x}_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Where:
t - is the t value
x_1 and x_2 - are the means of the two groups being compared
s_2 - is the pooled standard error of the two groups
n_1 and n_2 - are the number of observations in each of the groups.
Shapiro Wilk test/Normality test - The Shapiro–Wilk test is essentially a goodness-of-fit test. That is, it examines how close the sample data fit to a normal distribution. It does this by ordering and standardizing the sample (standardizing refers to converting the data to a distribution with mean and standard deviation).

$$W = \frac{\left(\sum_{i=1}^{n} a_i x_{(i)}\right)^2}{\sum_{i=1}^{n}(x_i - \overline{x})^2}$$

where:
- x_i are the ordered random sample values
- a_i are constants generated from the covariance, variances, and means of the sample (size n) from a normally distributed sample.

Kolmogorov-Smirnov test - is significant (e.g. p'<'. 05) then it indicates that the distribution of our sample is significantly different from the distribution against which it is being compared, e.g. a normal distribution (therefore the sample distribution does not fit the assumption of normality).
The p-value is the probability of obtaining a test statistic (such as the Kolmogorov-Smirnov statistic) that is at least as extreme as the value that is calculated from the sample, when the data are normal. Larger values for the Kolmogorov-Smirnov statistic indicate that the data do not follow the normal distribution.

$$D = Maximum|F_o(X) - F_r(X)|$$

Where –

- $F_o(X)$ = Observed cumulative frequency distribution of a random sample of n observations.
- and $F_o(X) = \frac{k}{n}$ = (No.of observations ≤ X)/(Total no.of observations).
- $F_r(X)$ = The theoretical frequency distribution.

The critical value of D is found from the K-S table values for one sample test.
Acceptance Criteria: If calculated value is less than critical value accepts null hypothesis.
Rejection Criteria: If calculated value is greater than table value reject null hypothesis.
For each bracket-arch wire combination, descriptive statistics such as mean, standard deviation, and minimum and maximum values were computed.
T-test was used to examine the means of FR of all combinations using the F distribution statistically.

Chapter IV
Presentation, Analysis and Interpretation of Data
This chapter presents, analyzes, and interprets the data collected in the study based on the research questions enumerated in Chapter I.
In the study conducted to investigate friction between arch wire-bracket assemblies, samples were divided into two groups: Set A consisted of Single Slot Brackets, and Set B consisted of Double Slot Brackets. The friction between the arch wires and brackets was tested by pulling the arch wires, specifically 0.016 x 0.022 stainless steel (SS) and 0.016 Niti wires, which were gripped by crimping brass fittings on one end and held by the arch wire-bracket assembly on the other end.
To measure the frictional forces, a load cell was utilized, which registered the force levels required to move the wire along the three aligned brackets. These force levels were then recorded and stored on a computer hard disk for analysis. The arch wires were moved at a crosshead speed of 1.0 mm per 6 seconds during the testing process.
The resulting load values of friction (FR) were calculated in Newtons (N), which is the standard unit of force. These values provide an objective measure of the friction experienced between the arch wire and the brackets in the different bracket types (Single Slot and Double Slot) and with different wire materials (0.016 x 0.022 SS and 0.016 Niti).
This experimental setup allowed to quantify and compare the frictional forces between the arch wire-bracket assemblies in the different groups. By understanding the frictional characteristics of these setups, orthodontic practitioners can make informed decisions regarding bracket and wire selection to optimize treatment outcomes and minimize the impact of friction on tooth movement.

Problem 1: What is the frictional force of .016 x .022 SS and .016 Niti using Single slot bracket?

Table 1. ***Descriptive Statistics (counts (N), Mean and Standard deviation) of the frictional force of single and double slot bracket***

Descriptive Statistics			
Frictional Force	N	Mean	Std. Deviation
Single slot bracket	15	5.05	1.37

Table 1 shows the descriptive statistics of the frictional force of single and double slot brackets measured in Newton (N). Descriptive statistics were expressed in terms of Counts (N), Mean and Standard Deviation. The mean frictional force of the single slot bracket was 5.05 N and the standard deviation was 1.37, while the mean frictional force of the double slot bracket was 4.10 N and the standard deviation was 1.88 shown in Table 2.

Problem 2: What is the frictional force of .016 x .022 SS and .016 Niti using Double slot bracket?

Table 2

Descriptive Statistics			
Frictional Force	N	Mean	Std. Deviation
Double slot bracket	15	4.10	1.88

Table 2 summarizes the frictional force measurements in Newtons (N) for double slot brackets. The descriptive statistics are the number of observations, the mean, and the standard deviation. The average frictional force for 15 samples of double slot bracket, it was 4.1085 N, with a standard deviation of 1.88766.

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The descriptive statistics provided in the table suggest that the average frictional force for the mean of 15 samples of double slot bracket. Additionally, the standard deviation values for both brackets indicate that there is variability in the frictional force measurements, with the double slot bracket showing higher variability than the single slot bracket. However, further analysis and interpretation would be required to determine if the observed differences in frictional force are statistically significant and meaningful in the context of the study or experiment.
The mean was higher in the 15 samples of single slot brackets (5.05 N) compared to the mean computed for 15 samples of double slot bracket (4.10 N); therefore indicating greater frictional force is observable in single slot bracket than double slot bracket as shown in Table 1.

Table 2. ***Shapiro-Wilk test (Test for normality)***

Table 3

Tests of Normality							
	group	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Frictional force	Single slot bracket	.13	15	.200*	.95	15	.63
	Double slot bracket	.13	15	.200*	.97	15	.91

Table 3 presents the test for normality (Shapiro-Wilk). This was done to test the comparability of the data for a parametric statistical treatment. The p-value for the single slot bracket was 0.66 which is above the p>0.05 which meant that the data was normally distributed; similarly, for the double slot bracket the p-value was 0.91 also above the p>0.05 which meant that the data was normally distributed. Thus, a

parametric test was applied, specifically Independent t-Test, which was used to compare the frictional force for both groups.
The results of the Shapiro-Wilk test for normality, which was conducted to determine whether the data for both the 15 samples of single with mean value of (5.05 N) and 15 samples of double slot brackets with mean value of (4.10 N) can be treated parametrically. The p-value obtained for the single slot bracket was 0.66, which is greater than the significance level of 0.05. This indicates that the data for the single slot bracket is normally distributed. Similarly, for the double slot bracket, the p-value was 0.911, which is also greater than the significance level of 0.05, indicating that the data for the 15 samples of double slot bracket is normally distributed as well.

Problem 3: Is there a difference in the frictional forces of Single slot and Double slot brackets in double wire technique?

Table 4. Independent t-Test Independent Samples Test

		t	df	Significance	
				One-Sided p	Two-Sided p
Frictional force	Equal variances assumed	1.56	28	.064	.128
	Equal variances not assumed	1.56	25.63	.065	.129

Table 3 presents the result of the Independent t-Test. The p-value was 0.12 which is above $p<0.05$, which means that there was no significant difference in the frictional force between the single and double slot brackets.
Table 3 displays the results of the independent t-test conducted to compare the frictional force between the 15 samples of single having mean of (5.05 N) and 15 samples of double slot brackets with mean value of (4.10 N). The p-value obtained was 0.128, which is greater than the significance level of 0.05. This indicates that there is no significant difference in the frictional force between the two groups. Therefore, based on the results of the independent t-test, we can conclude that the Single slot bracket and the Double slot bracket have similar levels of frictional force.

Discussion:

Orthodontic treatment involves the use of brackets and arch wires to align teeth and correct bites. However, a challenge that arises when using these components is the friction that occurs between them, which can have an impact on the movement of teeth and the overall effectiveness of the treatment.
The purpose of this study is to explore and understand the practical benefits of the double slot bracket invention in the field of treatment and biomechanics. Additionally, the study aims to provide valuable information about this bracket system, highlighting its significant advantages and benefits.
The double slot bracket invention refers to a specific type of bracket used in orthodontic treatment. Unlike traditional brackets that have a single slot, the double slot bracket features two slots, which can offer several advantages in the treatment process.
One of the primary objectives of this study is to perceive and examine the viable advantages of using double slot brackets. These advantages may include enhanced control and precision in tooth movement, improved treatment outcomes, and reduced treatment time. By comprehensively analyzing the effects and

results achieved through the use of double slot brackets, the study seeks to establish their viability as an effective orthodontic treatment tool.

Furthermore, the study aims to investigate how the double slot bracket invention can contribute to the advancement of biomechanics in orthodontics. Biomechanics in this context refers to the science and principles behind the mechanics of tooth movement and the forces exerted on the teeth during orthodontic treatment. By evaluating the performance and functionality of the double slot bracket system, researchers can gain insights into its impact on biomechanics, potentially leading to improved treatment techniques and protocols.

In addition to exploring the practical aspects, the study recognizes the importance of providing additional information about the double slot bracket system. This information may include details about the bracket design, materials used, manufacturing processes, and compatibility with various orthodontic appliances. By disseminating this knowledge, orthodontic practitioners, researchers, and manufacturers can have a better understanding of the bracket system's features, which can lead to its wider adoption and utilization in clinical practice.

The results obtained and analyzed in this study revealed that the average frictional force of the single slot bracket was measured to be 5.0553 N, with a standard deviation of 1.37965. On the other hand, the average frictional force of the double slot bracket was found to be 4.1085 N, with a slightly higher standard deviation of 1.88766. In terms of the distribution of data, the p-value for the single slot bracket was determined to be 0.663, indicating that the data followed a normal distribution. Similarly, for the double slot bracket, the p-value was calculated to be 0.911, confirming the normal distribution of the data as well. The analysis further revealed that the p-value of 0.128, which exceeded the significance level of $p<0.05$, indicated that there was no statistically significant difference in frictional force between the single and double slot brackets. These findings imply that, from a statistical standpoint, both types of brackets exhibit similar levels of frictional force and can be considered comparable in this regard.

Friction in orthodontics refers to the resistance experienced during the sliding motion between the bracket and the arch wire. This resistance is influenced by the materials of the bracket and the arch wire, as well as the force applied to the wire. As stated in the study by Jakati and Vijayvargia (2017), frictional force occurs when two bodies in contact have relative motion or the potential for relative motion.

Several factors contribute to the level of friction between the bracket and the arch wire. One important factor is the surface roughness of both components. A rougher surface will result in increased friction because there is more contact between the bracket and the arch wire. Therefore, it is crucial to maintain the smoothness of the bracket and the arch wire throughout the treatment process.

The size and shape of the bracket and the arch wire also play a role in friction. A larger bracket will create more friction compared to a smaller bracket since there is a larger surface area in contact with the arch wire. Similarly, a thicker arch wire will generate more friction than a thinner one, as mentioned in the study by Al Subie and Talic (2016).

To mitigate the effects of friction between the bracket and the arch wire, various methods can be employed. One approach is the utilization of low-friction brackets, which have smoother surfaces and minimize the amount of contact between the bracket and the arch wire. These brackets are designed to reduce frictional forces and facilitate easier tooth movement.

The findings of this study indicate that both single and double slot brackets can be considered as viable alternatives for orthodontic treatment. When deciding on the most suitable option, it is crucial to take into account the individual requirements of each patient. Additionally, it is essential to carry out further research in order to enhance orthodontic treatments.

The study suggests that both single and double slot brackets have their own advantages and considerations. Single slot brackets, have gained popularity due to their potential benefits. They exert less friction on the wires, potentially reducing discomfort and treatment time.

On the other hand, double slot brackets, have been gaining its worth as well particularly in Latin America and some Middle east countries and is used in orthodontics since its introduction in the market. They offer a reliable and effective method for moving teeth into proper alignment. Double slot brackets utilize elastic or metal ligatures to hold the wires in place, providing control and stability during treatment.

The selection of single or double slot brackets should be based on various factors, including the complexity of the case, patient preference, treatment goals, and orthodontist expertise. The individual needs and expectations of the patient should be taken into consideration to achieve the best possible outcomes.

While this study provides valuable insights into the efficacy of both types of brackets, it is important to acknowledge that orthodontic treatments continue to evolve. Further research and advancements are necessary to enhance treatment techniques, materials, and technologies. Ongoing studies can help refine orthodontic procedures, improve treatment outcomes, and ultimately benefit patients seeking orthodontic care.

Henceforth, the study indicates that both single and double slot brackets can be considered viable options for orthodontic treatment. Careful consideration of each patient's specific needs is crucial when selecting the most appropriate bracket type. Additionally, continued research and development in orthodontics are necessary to further enhance treatment options and improve patient experiences.

In summary, friction is a significant factor to consider during orthodontic treatment, as it can affect the movement of teeth and the overall success of the treatment. Surface roughness, size, and shape of the bracket and the arch wire all contribute to the level of friction experienced. Implementing low-friction brackets and ensuring the smoothness of both components are strategies employed to minimize friction and enhance the effectiveness of orthodontic treatment.

Chapter V

Summary of Findings, Conclusions and Recommendations

This chapter presents the summary of findings, the conclusion drawn from the data collected and analyzed, and the recommendations offered to help the readers and future researchers.

Summary of Findings

The summary of findings according to results obtained and analyzed is summarized below:

1. The mean frictional force of the single slot bracket was 5.0553 N and the standard deviation was 1.37965.
2. The mean frictional force of the double slot bracket was 4.1085 N and the standard deviation was 1.88766.
3. The p-value for the single slot bracket was 0.663 which is above the $p>0.05$ which meant that the data was normally distributed; similarly, for the double slot bracket the p-value was 0.911 also above the $p>0.05$ which meant that the data was normally distributed. The p-value was 0.128 which is above $p<0.05$, which means that there was no significant difference in the frictional force between the single and double slot brackets.

Conclusions:

Based on the findings, there is no difference in Frictional forces of arch wires between a single slot and a double slot bracket. Therefore, we can use both systems for leveling infra-erupted tooth such as high canine cases as an example and also palatally located tooth to mention a few knowing that both types of brackets provide similar levels of resistance to the movement of the arch wires, which is an important consideration in orthodontic treatment.

Recommendations

Based on the results that there is no significant difference in friction resistance between single slot and double slot brackets, the following recommendations can be made:

1. Consider both single and double slot brackets when selecting the best option for each patient. This decision should be based on a variety of factors, including the patient's individual needs, treatment goals, and budget.
2. Educate patients about the different types of brackets and the potential benefits and drawbacks of each. This can help them make an informed decision about their orthodontic treatment.
3. Continue to conduct research to confirm these findings and explore other factors that may influence friction and tooth movement, such as bracket design, wire material, and archwire size.
4. Manufacturers may want to reconsider their product lines and marketing strategies in light of these findings. They may want to focus on brackets that are as a more cost-effective and efficient alternative to the available brackets circulating the market
5. Dental educators should update their curriculum to reflect these new findings and challenge traditional assumptions about the superiority of each brand and type of brackets available. This can help prepare students to provide high-quality orthodontic care that is based on the most current and reliable research.

Overall, the results of this study suggest that both single and double slot brackets may be viable options for orthodontic treatment. It is important to consider the specific needs of each patient when selecting the best option and to continue to conduct research to improve orthodontic treatments.

Implications

Implications for Orthodontists

The latest research findings indicating there is no substantial difference in friction resistance between single slot and double slot brackets have impact for an orthodontist's practice.

Because of its capacity to apply force more precisely, Double slot brackets were presumably thought to give superior control over tooth movement. However, this recent study implies that single slot brackets may function similarly, which might have consequences for treatment planning and bracket selection.

When making treatment recommendations however, it is also critical to consider the study's limitations as well as the individual needs of each patient. This research, on the other hand, gives useful information that can improve your approach specifically in ease of application and comfort of patient to orthodontic treatment and perhaps lead to more efficient and successful outcomes for your patients.

Implications for Manufacturers

Manufacturers may need to advertise their product lines more and change marketing strategies in light of these findings. There may be an opportunity to focus on double slot brackets as a more cost-effective and efficient alternative to single slot brackets especially wherein double wire technique is needed as an option for treatment.

Implications for Future Researchers

This study opens up new avenues for research, as it challenges traditional assumptions about the superiority of double slot brackets in terms of controlling tooth movement. Researchers can now focus on investigating other factors that may influence friction and tooth movement, such as bracket design, wire material, and arch wire size.

Implications for Dental Students

Dental students, as future practitioners, must be aware of these new discoveries and be prepared to examine both single and double slot brackets when determining the optimal solution for each patient. Students should also be informed of the study's limitations and the significance of more research to corroborate these findings.

Dental students can better prepare themselves to offer high-quality orthodontic care based on the most recent and credible research by incorporating these new results into their coursework.

Implications for Dental Educators

This study may potentially be used by educators to educate critical thinking skills and underline the necessity of evidence-based practice in orthodontics. Students should be taught how to assess the validity and reliability of research studies, as well as the potential limits and consequences of the findings.

Dental educators may better educate their students to offer high-quality orthodontic care based on the most recent and trustworthy research by incorporating these new results into the orthodontic curriculum, resulting in more efficient and successful treatments for their patients.

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