"Evaluation of Torsional Strength of Ceramic Brackets Produced by Arch Wire Twisting Moment"

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ABSTRACT: -The purpose of this study is to evaluate the torsional strength of ceramic brackets produced by archwire twisting moment. In this study, three types of braces were used viz. monocrystalline, polycrystalline and stainless steel-reinforced type one each for maxillary right central incisor, lateral incisor and for canine tooth. Commonly known as traditional ceramic twin, traditional ceramic semi-twin and ceramic semi-twin with stainless steel reinforced channel respectively with a size of 0.42 x 0.55 mm. Stainless steel wire segments were used and the testing instrument was also fabricated to generate the wire torsion. To evaluate the torsional strength, 0.4 x 0.545 mm rectangular cross section stainless steel orthodontic wires were inserted into the bracket channels and submitted to torsion until they fractured.

Result of the study proved that according to the mean value, the ceramic brackets have maximum torque values in the order of: Polycrystalline ceramic semi-twin (30.38 N.mm), Polycrystalline ceramic semi-twin with stainless steel reinforced channel (32.34 N.mm) and Monocrystalline ceramic twin (38.22 N.mm).

Monocrystalline ceramic brackets produced the highest resistance to twisting forces. From finite element analysis it is clear that major fracture incidence in the ceramic brackets was at the incisal wings.

Keywords – archwires, braces, ceramic, orthodontics.

INTRODUCTION:

Patients who opt for orthodontic treatment today attribute great importance to dental aesthetics. In most adult patients ceramic braces are preferred over metal braces. Since the number of adults seeking orthodontic treatment has increased, orthodontists might have to use more esthetic appliances for the patients.[1] Until now, two major esthetic brackets, ceramic and polycarbonate, have been developed. Ceramic brackets are more frequently used than those made of polycarbonate, due to their better physical and mechanical properties, better color stability, esthetics and wear resistance than polycarbonate brackets. Nevertheless, ceramic brackets are more friable and generate more friction with the orthodontic wire when coming into contact with it.[1-2]

Because the working range in torsion of stainless steel wires is somewhat limited, precise delivery of torsional moment, based on the condition present in the oral cavity, is difficult. Torsional stiffness varies considerable within the various dimensional groups, this being the result of variation in cross-sectional geometry and material properties.[3] Metal-insert ceramic brackets generated significantly lower frictional forces than did conventional ceramic brackets, but higher values than stainless steel brackets. Beta-titanium archwires had higher frictional resistances than stainless steel and nickel-titanium archwires. No significant differences were found between stainless steel and nickel-titanium archwires.[4,6,8]

The traditional ceramic twin channel bracket showed the highest fracture strength, while the ceramic semi-twin with gold-reinforced channel bracket, obtained the lowest value. During sliding mechanics, the factor of frictional resistance is an important counterforce to orthodontic tooth movement, and it must be controlled so that lower optimal forces can be applied, higher frictional resistance requires more orthodontic force.[2,5-6]

Ceramic brackets are composed of aluminum oxide (Al_2O_3) and may be monocrystalline (a single aluminum oxide crystal) or polycrystalline (several aluminum oxide crystals fused at high temperatures). The major difference between polycrystalline and monocrystalline brackets is translucence. Monocrystalline brackets are more translucent than the polycrystalline type, which tend to be opaque. In addition, monocrystalline ceramic brackets are more resistant to fracture than the polycrystalline type due to the greater tensile strength of the monocrystalline alumina. Nevertheless, polycrystalline brackets are more frequently used because they are easier to produce and have a lower cost.[7,9-10]

In clinical use, however, they have problems including brittleness leading to bracket or tie-wing failure, iatrogenic enamel damage during debonding, enamel wear of opposing teeth, and high frictional resistance to sliding mechanics.[4] Brackets are subjected to various mechanical forces during orthodontic treatment. Therefore, esthetic brackets can deform or break during placement of a rectangular archwire into the bracket slot, during ligation of an archwire to the bracket, and during the transmission of torque and tip from archwire to bracket.[1,11-12]

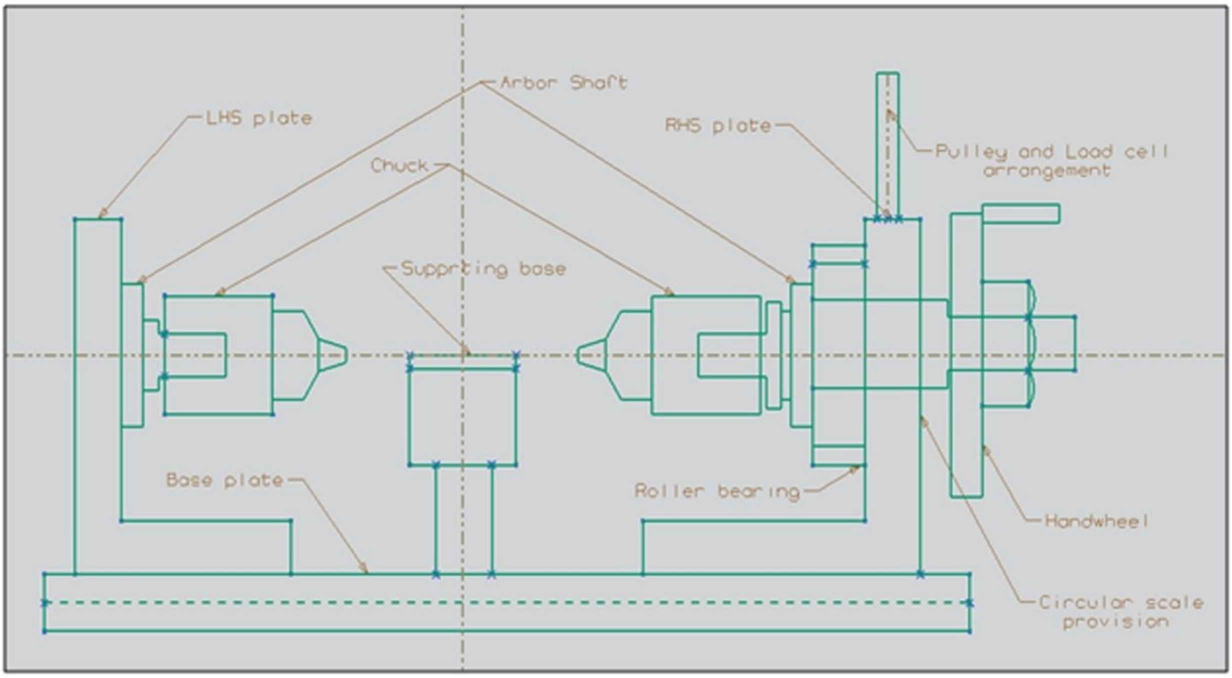
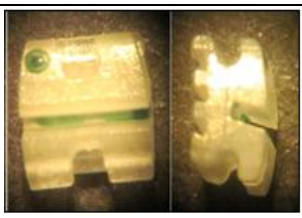
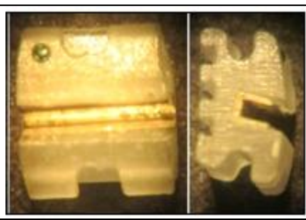


Fig. 1: Testing equipment to apply the twisting moment

Thus, the aim of this study is to evaluate the torsional strength of ceramic brackets produced by archwire twisting moment. The finite element analysis of bracket areas with higher incidences of fracture was also registered.

MATERIAL AND METHODS:

Three types of brackets are used for the study. Different designs are used one each for maxillary right central incisor, lateral incisor and for canine tooth (0.42 x 0.55 mm). Among the brackets (as shown in fig. 2) there were three brackets each of monocrystalline, polycrystalline and stainless steel-reinforced types; being traditional ceramic twin, traditional ceramic semi-twin and ceramic semi-twin with stainless steel-reinforced channel. Nine stainless steel archwire segments of 0.4 x 0.545 mm & 30 mm long stainless steel arches were also used in this study. Instantaneous glue which is used for fixing the brackets onto the supporting base. Tying rubber of 0.2 mm (0.008 inch) thick is used particularly for tying archwire into the brackets.

Ceramic Brackets ⇒ / Tooth Position ⇓	Polycrystalline semi-twin	Polycrystalline semi-twin with stainless steel reinforced	Monocrystalline twin
Central incisor			

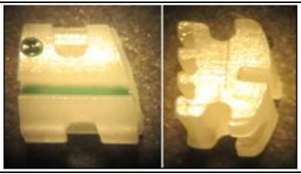
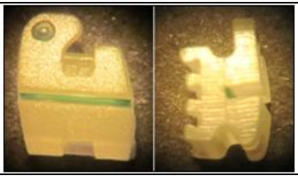
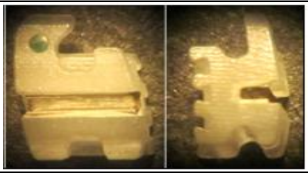
Lateral incisor			
Canine			

Fig. 2: Types of ceramic brackets with front and side views

The torsion testing equipment which was fabricated is as shown in fig. 1. According to wire size two holding chucks were selected. And side plates were used to mount a chuck that could hold and twist the wire without displacement in another direction. There was a provision given to the right side plate so that, it can slide along the base plate. The opposite side plate and chuck can hold the other end of wire in place and rotated simultaneously in same direction. In human maxillary jaw and mandibular jaw there are about five teeth are in straight position. And the average distance is about 30 mm so that, for experiment purpose we need to maintain this much distance in between the chucks. Thus, for adjustment purpose the centre distance between the chucks is maintained about 75 mm. At the end of the rotating shaft handwheel was connected to apply the twisting moment. And circular scale was also provided to measure the angular deviation. Also, supporting base for fixing the bracket is required.

For measuring the applied force; load sensor was required which was fixed to the appropriate position. Wire was connected to the sensor through the pulley and sensor was connected to the weighing indicator. Thus, we will get the exact force which will be applied during experiment.

Experimental Testing –

Connect the load cell which was attached to the torsion equipment to the weighing indicator but must cut off power while connecting the load cell. Weighing indicator connects to the switch and makes the supply ON. The indicator will show the zero reading. Then switch OFF the indicator. Hold the archwire into the chucks/crossbars which were mounted on supporting posts / side plates.

Then place the bracket in such a way that wire should insert through the bracket winglets and bracket should placed 6 mm from the end of the rotating chuck wire holder. This distance is standardized because it is considered to be an average inert-bracket distance between the maxillary incisors. And the other end of the wire remained 22 mm from the tip of the opposite chuck wire holder (as shown in fig. 3). The bracket will be fixed onto the supporting base with instantaneous glue. Then stainless steel archwire is legated onto the brackets with tying rubber.

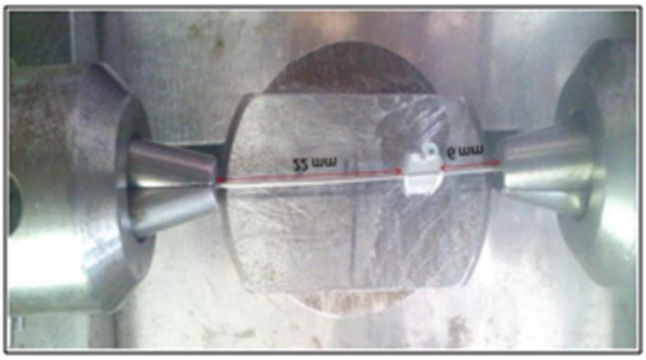


Fig. 3: Bracket position

Now, switch ON the indicator and it will show the zero reading. Now, twist the wire without displacement in another direction with the help of handwheel which is at the end of right side to rotate simultaneously in the same direction. The mechanical test will perform with gradual torsion applied to the archwire until the bracket fracture/deformation occurs. The amount of force (Kg) exerted by thread will be recorded from the indicator. Then torque calculations will be done.

RESULTS:

Torsional Strength –

The maximum force (Kg) recorded by the load cell is related to the twisting moment of ceramic bracket fracture. These torsion values of brackets are calculated from recorded force by load cell by following equation (1) –

$$T = F \times r \qquad (1)$$

Where,

T = Torque (N.mm),

F = Recorded force by load cell (Kg),

r = radius of shaft = 15 mm.

Among the ceramic brackets, the highest torsional strength / fracture strength (N.mm) is obtained with the monocrystalline traditional ceramic twin channel brackets. According to the mean value (N.mm), the ceramic brackets have increasingly deformation values in the order of: Polycrystalline traditional ceramic semi-twin channel brackets (30.38 N.mm), Polycrystalline traditional ceramic semi-twin with stainless steel reinforced channel brackets (32.34 N.mm) and Monocrystalline traditional ceramic twin channel brackets (38.22 N.mm) [as shown in table I].

Table I: Torsional strength (N.mm) of brackets produced by archwire twisting moment

Ceramic Brackets ⇒ / ⇓ Tooth Position	Polycrystalline semi-twin	Polycrystalline semi-twin with stainless steel reinforced	Monocrystalline twin
Central incisor	2	26.46	32.34
Lateral incisor	29.40	30.87	38.22
Canine	36.75	39.69	44.10

Angle of Twist –

Warping of rectangular (non-circular) cross-sections during application of torque makes the analysis of rectangular shafts difficult. For the analysis of rectangular shafts one of the important methods (based on experimental results) is called 'Membrane analogy' or 'Soap film analogy method' (mathematical analysis for rectangular sections based on theory of elasticity is rather difficult).[13]

According to soap film analogy method angle of twist in radians is given by –

$$\theta = \frac{\beta}{bh^3} \cdot \frac{Tl}{G} \qquad (2)$$

Where,

$$\beta = 3.5\left[1 + \left(\frac{h}{b}\right)^2\right] \qquad (3)$$

β = 5.585……approximately,

$$\beta = \frac{3}{1 - 0.63\left(\frac{h}{b}\right)\left(1 - \frac{h^4}{12b^4}\right)} \qquad (4)$$

β = 5.467……more accurately,

l = length of the shaft (i.e. between shaft's free end which is held by revolving chuck and bracket),

l = 6 mm,

G = Modulus of rigidity,

G = 73664.12 MPa.

According to the mean value (θº), the archwires have increasingly twisting values in the order of: Polycrystalline traditional ceramic semi-twin channel brackets (22.22º), Polycrystalline traditional ceramic semi-twin with stainless steel reinforced channel brackets (23.65º) and Monocrystalline traditional ceramic twin channel brackets (27.95º) [as shown in table II].

Table II: Angle of twist (θ°) of archwire to produce required torsional strength

Ceramic Brackets ⇒ / ⇓ Tooth Position	Polycrystalline semi-twin	Polycrystalline semi-twin with stainless steel reinforced	Monocrystalline twin
Central incisor	18	19.35º	23.65º
Lateral incisor	21.50º	22.58º	27.96º
Canine	26.88º	29.03º	32.26º

DISCUSSION:

Evaluation of the torsional strength of ceramic brackets submitted to archwire twisting moment was held due to the high friability and low tensile strength of ceramic brackets. This study was designed to evaluate the mechanical resistance to orthodontic torquing moments of various commercially available esthetic brackets.

All mechanical tests were performed under similar conditions to clinical use. The wire was twisted in the direction of the brackets' cervical wings, simulating the lingual torque of a dental root. In a finite element study, when lingual root torque was applied, it was observed that the stress tended to concentrate at the bracket's incisal base and irradiate to the incisal wings, making the ceramic bracket more fragile. The major fracture area of the ceramic brackets was at the incisal wing that is about 70%.

Design and manufacturing process are factors that determine the strength of ceramic brackets, and the channel and winglet designs are critical for the strength of the accessory. This study confirmed that ceramic is a resistant and rigid material. One of the factors responsible for the higher fracture strength of the twin ceramic bracket may be due to its fabrication method. For these brackets, the fabrication process is molding by injection, which makes it possible to obtain uniform surfaces with fewer irregularities when compared with brackets fabricated by the machining method. Injection molded brackets have a smoother finish than machined brackets, thus reducing the number of surface defects. Thus, these brackets have greater fracture strength under traction when compared with twin ceramic brackets fabricated by machining, which show damage and defects caused by the equipment during fabrication, and serve as foci for fractures.

In this study the 0.4 x 0.545 mm stainless steel arch was used because it is the most commonly used type of arch by orthodontists during the stages of control and torque incorporation in orthodontic treatment.

CONCLUSION:

It is concluded that the monocrystalline traditional twin ceramic bracket presented the highest torsional strength during torque simulation in comparison with the polycrystalline traditional semi-twin ceramic and polycrystalline traditional semi-twin ceramic with stainless steel reinforced channel brackets, due to the method of fabrication.

Other concluding points are:

1) Metal slots in the ceramic brackets did not effectively reduce friction.

2) Monocrystalline ceramic brackets produced the highest resistance to sliding forces.

3) The area of major fracture incidence in the ceramic brackets was at the incisal wing.

4) The size of esthetic brackets did not influence the results of resistance force values. The lower resistance fracture values of ceramic brackets seemed to be associated with the absence of the reinforce slot rather than to the size variation.

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