INTRODUCTION

The increasing demand for esthetics in the posterior region of the mouth and environmental concerns about restorations containing metal were behind the evolution of new techniques for fabrication of posterior inlays, onlays, and crowns [1]. Such restorations have several advantages, including lifelike appearance, biocompatibility, wear resistance, and color stability. However, their drawbacks include brittleness, especially glass or feldspathic ceramics, susceptibility to fracture, causing excessive wear to oppose dentition, requiring more involved tooth reduction, and being technique sensitive. When non-metallic crowns undergo fracture, the fracture typically originates from flaws or defects in the intaglio surfaces. Subcritical crack growth follows, which is enhanced in the aqueous environment. Ceramic materials are particularly susceptible to the tensile stresses, and mechanical resistance is also strongly influenced by the presence of superficial flaws and internal voids. Such defects may represent the sites of crack initiation.
This phenomenon may be influenced by different factors such as marginal design of the restoration, residual processing stress, magnitude and direction and frequency of the applied load, elastic modulus of the restoration components, restoration–cement interfacial defects, cement film thickness and oral environmental effects. The introduction of computer-aided design / computer-aided manufacturing (CAD/CAM) technology in dentistry enabled dentists to use new treatment modalities and changed the design and application limits of all-ceramic restorations as the demand for esthetics in the posterior region of the mouth has increased. Recent lithium disilicate restorations have provided functional, biocompatible, and esthetic demands. The strength of an all-ceramic restoration depends not only on the fracture resistance of the material, but also on a suitable preparation design, cement space thickness and adequate material thickness.

The lack of sufficient relief spaces in these areas impedes the flow of cement beyond the occlusal portion of the casting, resulting in incomplete seating due to hydraulic pressure [2]. Pilo, et al. said when the crown restoration precisely fits the prepared tooth, the escape pathway of cement between the crown restoration and prepared tooth surface become more difficult [3]. The final effects are creation of premature, occlusal contacts, inappropriate proximal contacts, marginal discrepancies and lack of coziness [4]. Many methods have been suggested previously in order to minimize post cementation marginal discrepancy such as Venting [5]. Cement escape channels and Internal relief space Internal relief space for cement has been shown to increase the marginal fit between restoration and prepared tooth surface become more difficult [3]. The final effects are creation of premature, occlusal contacts, inappropriate proximal contacts, marginal discrepancies and lack of coziness [4].

Prior to teeth preparation, the pencil was used to demarcate the future finish line position. In order to obtain standardized preparation, a high speed water coolant handpiece connected and secured to dental surveyor upper arm, while acrylic specimen holding the tooth was adapted to the surveyor mobile lower member, by this way the long axis of the bur can be kept parallel to the long axis of the tooth throughout the cutting procedure. Each specimen was prepared to receive the recommended following preparation guidelines by ivoclar vivadent: anatomical occlusal reduction, 1 mm chamfer finishing line all around the tooth with a total circumferential axial reduction of about (1.5 mm) and 6 mm total axial tapering (Figure 2).

All specimen is randomly divided into two groups A and B by the cement space thickness (n=8): the cement space parameter in Group A was set at 100 mm and for Group B was set at 120 mm. (Figure 3). Each sample were scanned using the 3-shaped intra-oral digital scanner (3-Shape, Copenhagen, Denmark) with Exo Cad software to create a 3D digital image for all teeth. The crowns were then milled with the MC X5 (Sirona Dental System, Germany) milling machine, IPS e.max CAD ceramic lithium disilicate blocks for CEREC and In Lab (Ivoclar Vivadent, Schaan, Liechtenstein).

A custom-made holding device was especially fabricated to be used as a screw that secured the lithium disilicate crown on the natural tooth sample during marginal checking and cementation procedure to maintain standardized seating forces. The device was designed to have a load sensor attached to it. Furthermore, a modification was done on this device so that it will hold the crown parallel to the path of insertion of the prepare tooth during crown seating procedure by attaching the vertical arm of the device to the vertical arm of the surveyor. In order to apply the seating force more evenly...
and parallel to the path of insertion, a square custom-made mold of 8 mm × 4 mm with central round hole about 1 mm larger from the crown circumferential was attach to the tighten screw end of the device. This central hole was filled, later on, during cementation procedure with special type of silicon to cover 3 mm of occlusal surface of each cemented crown. Each crown was seated on the tooth sample with a standard load of 5 Kg (≅50 N) (Figure 4) [8].

Prior the cementation procedure for all groups, the teeth were cleaned by alcohol, the luting agent were injected inside the inner surface of the crown until it complete filled. Each crown was, then, filled with the luting cement and seated over its respective tooth with finger pressure initially then a static load of 5 Kg was applied for 6 minutes according using the specimen holding device. Excess material was removed with a fine micro brush before complete polymerization. Each cemented specimen was kept for one hour to bench set. All specimens were then stored in distilled water at room temperature and then tested after one week after cementation [9].

Testing Procedure A single load to failure test using universal testing machine (Laryee, Beijing, China) (Figures 5 and 6) was used to assess the strength of the cemented crowns. In order to be suitable with the size of the specimen that used in this study, two modifications have been done on Instron test machine, one involved the upper jaw while the other involved the lower jaw. For upper jaw, Instron testing machine was mounted with a movable rod with semispherical head of 4
mm diameter attached to the upper jaw through the loading piston, while for the lower jaw, specially designed sample holding device was mounted to the lower jaw of the testing machine to securely hold the specimen.

After one week of storage in distilled water, the specimen was secure on their position on Instron testing machine, the occlusal surface of the crown was covered by 1 mm thick rubber sheet, the loading force was then applied at the center of occlusal surface along the long axis of cemented crowns with a crosshead speed of 0.5 mm/min until fracture occurred [10].

All specimens were loaded up to fracture and a computer connected to the charging system automatically recorded the total breaking load of each sample in Newton (N) when rod's end press on the slope of the cusps. Also, after the fracture strength test was completed, each specimen was examined visually using magnifying loupes (6 x) to assess the fracture mode as shown in Burke’s classification (Table 1).

RESULTS

The descriptive statistics including the mean, standard deviation, minimum and maximum
values of the fracture strength in (N) of the two different groups are shown in Table 2.

Also from the Table 2 with (B) group in which the crowns are manufactured with cement space thickness 120 Mm , the highest mean value of the fracture strength as (1936.25 N), while the mean value was recorded in the groups (A) with cement space thickness 100 Mm is (1688.75N).

Additional t test also done to show the difference between the groups that luted with the same luting agent but with different cement space thickness as follow in Table 3. T test shown the significant difference of the fracture strength of the crowns fabricated with different cement space thickness and the same luting agent Table 4.

### DISCUSSION

#### Material and method

In this analysis, freshly extracted human natural teeth are selected to be used as abutment teeth since the fracturing strength of all-ceramic restorations is heavily dependent on the supporting abutment’s elastic component [11]. In addition, the use of natural teeth permits restoration adhesive cementation and more clinical relevance [12].

Due to the relative ease of their selection from patients in need of orthodontic treatment and can be collected as a sound tooth, maxillary first premolars were chosen for use in this study. Furthermore, relative to other teeth, maxillary premolars are the least variability in morphology [13].

To mimic the help of alveolar bone in a healthy tooth, all teeth samples are individually embedded in a cold cure acrylic resin block up to 2 mm apical to the CEJ [14].

Tooth preparation is dependent on material for all-ceramic crowns. The stated strength of any ceramic material by the manufacturers depends entirely on the material thickness and the design of the preparation. Anything less than following the recommendations of the manufacturers will lead to a weaker final restoration. On the other hand, lithium disilicate's least suggested axial reduction is 1 mm. Therefore, the manufacturers of the materials used in this study recommend deep chamfer finishing line in this study regarding the type of finishing line. This type of finishing line has been found to provide better marginal adjustment of all-ceramic [8,15].

Planar occlusal reduction was performed because a clinical simulation should be used to prepare a tooth or model in vitro [16]. In addition, it was found that planar occlusal reduction will provide better marginal adaptation of the crown restoration when chamfer finishing line was used [8]. To obtain standardization for all specimens, teeth were prepared occluso-gingivally at a height of 4 mm [17]. Tooth preparation was performed using a modified dental surveyor to monitor tooth preparation variables including the degree of axial taper, finish line layout, and insertions route [18].

Digital impression using intra-oral scanner was used in this study to overcome the errors that
could occur during the steps of conventional impression making, including the dimensional changes of the impression material and gypsum used to manufacture the master model [19]. The same digital process was used for the manufacture of crowns for standardization purposes, including the use of the same design software, design mode, parameters of restoration and milling unit. Design mode "Biogeneric Reference" using a first premolar dentoform as the reference tooth was selected in this study to provide a standardized morphology for crowns of all teeth.

In this analysis, dual-curing resin cement was used to ensure a high conversion rate and full cement healing due to differences in the degree of translucency of the materials used since these cements were cured by two mechanisms: chemical and photo-initiated. If insufficient light penetrates through the reconstruction during the cement's final light curing, the concrete is chemically cured [20]. Each crown was seated under a constant load of 5 kg (approximately 50 N) during cementation to simulate the biting force during clinical cementation [21]. During the load application, a piece of rubber material was placed on the occlusal surface of the crown to spread the load evenly across the entire occlusal surface and to mimic the cotton roll cushion effect medically used during crown cementation [22]. During the seating and cementation process of the lithium disilicate crown to the preparation teeth, a Specimen Holding and Cementing Device was used in this research [8]. A modification has been added to this tool, this improvement allows for more reliable crown restoration seats for all specimens by allowing a single uniform load path perpendicular to the occlusal surface during cementation In this research, single load to failure testing was used to check the fracture strength of crowns as this method provides useful information to compare the materials tested without the input of confounding variables from fatigue testing [23].

The load was applied in this experiment at a crosshead speed of 0.5 mm / min as it was found that lower speeds were followed by greater plastic deformation and higher fracture strength measurements could be obtained [24].

Many forces act in all possible directions in the dynamic masticatory process, the most important being the compressive force; therefore, the choice of load application parallel to the long axis of the tooth was chosen to simulate the physiological function and obtain a degree of non-axial loading through existing occlusal contact variations [7]. Placing a piece of rubber between the load applicator and the tested crown was intended to act as a stress breaker to prevent damage caused by the load applicator's direct contact with the tested crown and to mimic the cushion effect of food between opposing teeth [25].

Comparisons among groups
In this study, the statistically highly significant differences in the fracture strength between different groups could be attributed, in general, to the variable internal fitness of all ceramic crown restorations that fabricated with different cement space thickness, in which the higher cement space thickness of fabricated all ceramic crown had a higher fracture strength. These result findings are agreed with different previous studies like [26-29]. Regarding to previous studies, increased cement space thickness is correlating with decreased seating discrepancies and thinner cement thickness. Also, a modulus of elasticity of the supporting structure has a role on the fracture strength of the all ceramic restoration, in which the higher the elastic modulus, the higher the load to the failure. The modulus of elasticity of the dentin is (16 GPa) and that of the luting cement is (6 to 8 GPa), so the thinner cement thickness is preferred for higher fracture strength of overlying all ceramic crown. The way to have a thinner well distributed cement is by decreasing the hydraulic pressure while crown seating. This can be achieved by increase the cement space thickness of fabricated crown to provide more space for escape of excess cement during crown seating [30]. Despite the statistically significant differences in fracture strength between the different subgroups, it should be noted that the mean value of the fracture strength of the crowns in all groups exceeded the maximum bite strength in the premolar region (450 N) [31].

Mode of fracture
In this study, most of the samples of all groups showed severe fracture of the crown and tooth (catastrophic failure). This mode of fracture could be attributed to the nature of fracture test used, the single load to failure test, whereby the inclination of the cusps and the position of the load applicator during loading play a major role.
in determining the fracture behavior. Crown anatomy of the upper premolars with the sharp angle between the buccal and palatal cusps makes these teeth more susceptible to a mesio-distal split vertical fracture under occlusal load [32]. This mode of fracture was also found in previous studies done [33] and [34] who all found that static load to failure test provoked splitting of the crowns from the central fossa through the abutment mesio-distally below CEJ. On the other hand, this mode of fracture suggests a strong bond between the cemented crowns and their respective teeth owing to the adhesive cementation protocol used in this study. It has been shown that adhesive cementation reduces the risk of debonding of all-ceramic restorations due to its high bond strength to the tooth structure and ceramic restorative materials.

LIMITATION

One of the main limitations is that the study done in vitro (non-vital teeth) and the dentine quality of the samples is not identical exactly 100%.

CONCLUSION

The using of 120 μm cement space thickness with lithium disilicate crown fabrication to increase the fracture strength.

REFERENCES


