# Role of finish lines design on stress distribution in fixed partial denture

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**ABSTRACT**
All-ceramic restorations have been widely used in prosthodontics as metal-free restoration because of their esthetics, biocompatibility, and inert properties. However, fracture remains a complication for all-ceramic restorations. All-ceramic posterior restorations encounter significant fracture after 5 years of usage than anterior region. Stress distribution in all-ceramic restorations during mastication is higher on cervical margin than other surfaces according to finite element analysis. Shoulder and chamfer finish line are recommended designs for maximum fracture resistance of restoration and had influence in stress distribution. Mechanical properties of restoration material such as flexural strength, modulus of elasticity (ME), and fracture resistance are important factors that must be considered for its durability. Increasing ME of restoration material will increase strength of fracture. Zirconia usually used because of its superior fracture resistance among other ceramic material (ME±205 GPa). Shoulder is recommended in zirconia because of greater fracture resistance but other literature suggests chamfer. Lithium disilicate has an improved physical properties and translucency ceramic restoration and is recommended as an alternative treatment (ME±96 GPa). In lithium disilicate, shoulder and chamfer have almost equal fracture resistance. PEEK is a thermoplastic semi-crystalline material with ME near human cortical bone (±3.6 GPa) with shock absorption properties. This literature review role of all-ceramic restoration finish lines design on stress distribution. Shoulder and chamfer still the main choice in FPD but which design is most appropriate still undecided.
**Keywords:** finish lines design, zirconia, lithium disilicate, PEEK, stress distribution
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## INTRODUCTION

Over the past decades, all ceramic dental materials have been widely used in prosthetic dentistry as metal free restoration due to their good esthetics, biocompatibility, and excellent inert properties.[1,2] Improvement of microstructure and physical properties from all ceramic crowns have been developed to the posterior region as an alternative treatment for dental defects, and it has been suggested that these material are as reliable as metal-ceramic crowns, therefore all ceramic crowns are currently considered the gold standard. However, fractures remain a complication of all ceramic restorations. One of the main problems with all ceramic restorations is the possibility of fracture under occlusal and lateral forces.[1,3,4]

The most important factor influencing the fracture rate of an all-ceramic crown is the position of the restored tooth in the mouth, this position determining the magnitude and direction of the occlusal force. Ferrario et al reported that the greatest force occured in molars, decreased in the premolars, and became only one-third to one-fourth of the original value for the incisors. Goodacre et al. reported that the clinical fracture rates of ceramic crowns differed between types of restored teeth, namely 21% for molars, 7% for premolars, and 3% for anterior teeth. In a systematic review by Xiaodong et al., all ceramic crowns showed an acceptable 5-years fracture rate of 4.4% regardless of the materials used with molar crowns (8.1%) showing a significantly higher 5-years fracture rate than premolar crowns (3.0%), and the difference between anterior crowns (3.0%) and posterior crowns (5.4%) also achieved significance. Fractures were classified as core fractures or veneer fractures. The determinants of fracture of an all-ceramic restoration depends on the fracture resistance of the material, finish line design, appropriate thickness of the material, magnitude and direction and frequency of applied loads, interfacial defects of restoration cement, and oral environment effects. Finite element analysis studies has been applied to investigate fracture in fixed partial denture. The results showed that stress was mostly concentrated in the cervical region of the restoration. Therefore, finish lines design may affect the fracture resistance of fixed restoration.[1,2]

This literature review is aimed to discuss the role of finish lines design on stress distribution in fixed partial denture

## LITERATURE STUDIES

### Restoration material

Restorative material considered to be a factor that influence the biomechanics, that is stress distribution and cusp deflection, during masticatory movements. It has been reported that some crown

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fracture due to the relatively low mechanical resistance of the ceramic crowns, which may be related to the large masticatory forces applied to the premolars and molars as well as to the brittleness of the inherent of ceramics. Ceramic materials are very susceptible to tensile stress and mechanical resistance which is also greatly affected by the presence of superficial flaws and internal voids. The defect may represent sites of the crack initiation. The modulus of elasticity of restorative materials is an important factor in crack initiation and propagation in dental ceramics. Scherrer and de Rijk reported that the fracture load increased as the elastic modulus of the material or supporting structure increased. Farah et al. reported that the base material should have the highest possible modulus of elasticity to support restorations from intermittent forces during mastication. The choice of crown material has a great influence on the maximum principal stress in the crown. Increasing the stiffness of the crown material concentrates more stress within the crown, whereas crowns made from a material with a lower stiffness transfer more stress to the cement layer and the tooth supporting core.[5]

Leucite-reinforced glass-ceramic have been used for more than 30 years for the esthetic appearance in the anterior region for single crown. In 1998, pressable lithium disilicate all-ceramic material IPS Empress 2, which exhibits higher mechanical strength than its predecessor and is suitable for three-unit fixed dental prostheses in the anterior region, was introduced on the market. Due to its opacity, this material needs to be veneered. In 2007, IPS e.max Press material, which is a new pressable lithium-disilicate glass ceramic, was used to improve its mechanical properties with good esthetics and translucency. In addition, the range of indications for use include anterior and posterior teeth. Lithium disilicate has a modulus of elasticity of ± 96 GPa.[6]

Meanwhile, zirconia material is currently considered as the most suitable material for posterior restorations because it has higher flexural strength, fracture strength and fracture toughness of 6-15 MPa.m$^{1/2}$, flexural strength of more than 900 MPa, high Vickers hardness 1200-1350 HVN and modulus of elasticity ±205 GPa compared to other ceramics such as alumina, glass ceramics and lithium disilicate. A yittria-tetragonal zirconia core with its stabilized tetragonal phase is indicated in the high stress sector because of its ability to resist crack propagation. However, the high incidence of veneer chipping and porcelain veneer fracture is a frequently reported technical complication. The clinical survival rate of tooth supported by zirconia-based all ceramic crowns can be as high as 95.9–98.5% after 5 years but decreases by 10 years to 67.2%. Beuer et al. reported a significantly higher fracture load (2286 N) in a single zirconia crown with a shoulder finish line design compared to the other conservative finish line designs. Ezatollah et al evaluated the effect of two different finish line designs namely chamfer and deep chamfer of zirconia core restoration and from these results showed that both finish line designs had high fracture resistance over masticatory forces so that both designs could be used. However, since fracture resistance tends to favor chamfer finish line design, it is recommended because of its efficiency in biomechanical characteristics of posterior single all ceramic crown restorations. Compared to other ceramics, zirconia shows the highest stability as a framework material. However, the most frequent technical problem in fixed dental prostheses with zirconia framework is minor chipping or extensive fracture of the ceramic veneer.[3,6–9]

Recently, PEEK material has been used as an alternative to single crown restorations due to its material properties but research on this material is still ongoing. Polyetheretherketone (PEEK); thermoplastic crown type is a new material that has been introduced in the field of dentistry, namely bioactive high-performance polymer (BioHPP); containing 20% ceramic filler. This PEEK thermosplastic material is characterized by good biocompatibility, good wear resistance, chemical stable, light weight and adequate mechanical properties allowing it to be a suitable alternative material for ceramic restorations. BioHPP is indicated for the manufacture of implant fixtures, crown/bridge fixed denture prosthesis frames and removable den-tures, as well as for implant frames and restorative implant parts. The modulus of elasticity of this material is 4-6 GPa close to the modulus of elasticity of bone allowing it to act as a load absorber agent; thereby, reducing the forces transmitted to the restoration and the tooth roots. The advantages of using this material are the elimination of allergic reactions, good polishing properties, and low plaque adhesion. In addition, despite its low modulus of elasticity and hardness, its high wear resistance makes it competitive with metal alloys. However, research evaluating the material properties of these materials is still limited.[1,5,10]

## Finish lines design

The tooth preparation is a very important factor in determining the strength of all ceramic crown.

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Shoulder and chamfer finish line design are the most widely used designs for fixed partial dentures. Shoulder finish line design is usually chosen for full all crown restorations. The wide ledge of the shoulder finish lines provides resistance to occlusal forces, minimizes stresses that can cause porcelain fracture and leaves space for healthy restoration contours and maximum esthetics. The disadvantage of the shoulder finish line design is that the tooth structure is less conservative and the stress concentration is at an internal angle of 90° on the finish line, making it susceptible to coronal fracture. Chamfer finish line is a concave extra coronal finish line that provides greater angulation than the knife-edge design and a smaller width than the shoulder design. The advantage of chamfer finish line design is more conservative, has clear margins, easy to identify, and provides room for more adequate bulk of material and the development of anatomically precise axial contours. Chamfer finish line design requires care to avoid leaving a lip of unsupported enamel. Several studies have been carried out to evaluate the effect of finish line design on load at fracture, but the results of these studies are inconclusive. Some studies have found that finish line design has an effect on fracture resistance, while others have seen no such effect. A larger rest area for margins, such as shoulder finish line design, is suggested to ensure a better pattern of stress distribution during occlusal loading, but the results of studies on this subject are inconsistent because some authors have found no relationship between the finish line design and the fracture strength of all ceramic crowns, while significant results were found by other authors. Shoulder finish line design and several other authors have proposed a deep chamfer finish line design for maximum fracture resistance of fixed restorations. Jalalian et al. suggested deep chamfer finish line design for higher fracture resistance to improve the biomechanical performance of zirconia posterior single crown restorations. Pasha recommends chamfer finish line design because it has high fracture resistance against posterior bite forces for better biomechanical performance.[1,10–13]

### Stress distribution

Finite element analysis (FEA) is a digital test carried out by simulating experimental studies, this analysis test always represents a simplification of clinical scenarios. The FEA has become a powerful test technique in dental biomechanics due to its flexibility in calculating stress distributions in complex structures. The FEA allows the study of stress distribution through model simulation, which can be used to examine the role of various design. The advantages of the FEA test compared to in vitro laboratory tests are lower costs and faster. The disadvantage is that it is a computerized in vitro study in which clinical conditions may not be fully replicable.[3,6,14,15]

It is known that the design of the finish line is one of the factors affecting the marginal adaptation and fracture resistance of the crowns. The fracture pattern of a fractured crown during clinical use indicates the origin of the fracture is at the cervical margin of the crown or from the intaglio surface of the crown. In one study, FEA was used to study stress distribution during mastication in the maxillary second premolars restored with metal ceramic crowns and compared with the non-restorable tooth, a large stress was recorded on the cervical line of the restored tooth. The load on an all-ceramic crown during mastication has been reported to be higher near the cervical margin than on the occlusal surface, and thin margins may be the cause of fracture according to fractographic and FEA. The cervical margins have also been reported to be vulnerable, and during clinical use, cracks may be induced from the occlusal surface to the thin margins.[1,3,15]

## DISCUSSION

In the literature, data showed that differences in the finish line design clearly affect the stress distribution to the crown margin. Stress distribution can be used as an indicator of the biomechanical behavior of crown restorations. The FEA helps in analyzing stress distribution within crown. Most studies of stress distribution in single crown restorations have shown that the cervical area has high stress. The location of the stress depends on the crown structure, the abutment material and finish line design. The best choice of finish line design for fixed dentures is still uncertain. Rammersberg et al, agree that chamfer finish line design has the greatest stability for posterior all ceramic crowns. Jalalian et al. stated that fracture resistance with the shoulder finish line design was lower than the chamfer finish line design of the InCeram full ceramic restoration. Jalalian et al. in another study showed lower fracture resistance of CAD/CAM zirconia posterior crowns with a shoulder finish line design compared to chamfer design. However, Di Lorio et al, evaluated the effect of the shoulder and chamfer finish line design on fracture resistance of the Procera full ceramic crown core and concluded that fracture resistance with shoulder finish line

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design was higher chamfer finish line design. De Jager et al, performed a FEA to assess stress distribution on full ceramic restorations and concluded that chamfer finish line design was more suitable for posterior restorations. Cho et al, evaluated the effect of finish line design on fracture resistance of composite-reinforced ceramic restorations and demonstrated that the fracture resistance of chamfer finish line design samples was significantly higher than shoulder finish design. Potikel et al, assessed the fracture resistance of the teeth restored by different full ceramic systems and showed no significant difference between the groups. Roh et al and Ahmadzadeh et al demonstrated that shoulder and chamfer finish line design did not affect the fracture resistance of the IPS-emax posterior single crown. Rocha et al. stated that finish line design of crown proved susceptible to fractture with maximum stress in the area using FEA. Turk et al. in his study using 3D-FEA method showed that rounded-shoulder finish line design had a higher Von-Mises stress value than chamfer finish line design model. D'Souza et al. concluded that the area with maximum stress was concentrated in the cervical third region of the single crown root of the mandibular posterior teeth when given the maximum bite force using FEA. Magray et al, using FEA evaluates von Mises stress having the highest value in the chamfer finish line design compared to the shoulder finish line design. Miura et al, stated that using 3D finite element analysis, shoulder finish line designs can show better clinical performance and can be expected to reduce fracture risk in all ceramic crowns.

It is concluded that shoulder and chamfer finish line design still the main choice in fixed partial denture. Wide ledge of shoulder design provides resistance to occlusal forces and gives space to healthy restoration with maximum esthetic but it is less conservative of tooth structure and stress concentration at 90° internal angle of finish line hence conducive to coronal fracture. Chamfer finish line has concave form. It provides greater angulation than knife edge and less width than shoulder. Chamfer are more conservative with distinct margin and easy to identified. The most appropriate finish line design for longterm durability is still undecided. The choice of crown restorative material has an influence on the stress distribution for a longterm crown restotoration. Careful planning of the finish line design and selection of restorative materials is important before carrying out treatment.

Further research in stress distribution evaluatting proper finish line design that complement with restorative material for long term of fixed restoraration is needed to provide a further explanation.

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