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Original Research

3D FEA Evaluation of Correlation between Stress Distribution and Taper on Full Ceramic Fixed Partial Dentures: An Original Research

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***ABSTRACT*:**

Introduction: The Fixed Partial Denture (FPD) is considered to be the weakest at the connector region and can lead to the formation of micro-cracks. It has been observed that abutment teeth with higher taper angles during tooth preparation had a greater bulk of connector which led to increase in strength of the connector and the full ceramic FPD. **Objective:** To determine the effect of taper of abutment teeth in the stress distribution of full ceramic 3-unit fixed partial dentures. **Material & Methods:** Two fixed partial denture (FPD) models were created on a dentate human skull. The FPDs replaced mandibular second premolar and the adjacent first premolar and first molar served as the abutment teeth. Computerized Tomography (CT) images of the skull were taken and exported to solid modeling software, which were then transferred to the Finite Element Analysis (FEA) program. The tapers were different in each model, the first being 14 degrees and the second 24 degrees. Von Mises resolved stresses as well as Principal stresses were recorded for each model at the connector as well as the abutment teeth. **Results:** The maximum Von Mises stresses for the first model with a taper of 14 degrees were 21 MPa at the connector, 5 MPa at the first premolar region and 2 MPa at the first molar region. The maximum Von Mises stresses for the second model with a taper of 24 degrees were 17 MPa at the connector, 5 MPa at the first premolar and 1.8 MPa at the first molar region. The maximum Principal stresses for the first model with a taper of 14 degrees were 16 MPa at the connector, 0.5 MPa at the first premolar region and 0.3 MPa at the first molar region. The maximum Principal stresses for the second model with a taper of 24 degrees were 14 MPa at the connector, 0.4 MPa at the first premolar and 0.3 MPa at the first molar region. **Conclusion:** Increased taper may lead to decrease in stress at the region of the FPD connector.

Keywords: FPD, FEA, full ceramic, taper, stress distribution.

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INTRODUCTION:

The success of FPDs has been assessed by several researchers in the past.[1-4] To estimate the stresses that are produced under load stress analysis is used.[5-7] The FEM can be used to reveal details of FPD displacement and stress distribution under loading that cannot be revealed by the simple application of the stress analysis.[8] A finite element analysis was conducted through which principal and Von Mises stresses were measured. Briefly stated it may be shown that for any general point, o, in a body, there exist three perpendicular planes at o, on which the shear stresses vanish. The remaining normal stresses are called the principal stresses. The difference between maximum and minimum of principal stresses is a criterion of material yield. This difference should be smaller than two times the yield strength of material to prevent the yielding. There is another criterion which is more useful to predict failure. It is called Von Mises stress, i.e. the amount of normal stress causes the material to be distorted.

The objective of this study was to determine the effect of taper of abutment teeth in the stress distribution of full ceramic 3 unit fixed partial dentures.

MATERIALS & METHODS:

In the current study, two fixed partial denture (FPD) models were created on a dentate human skull. The FPDs replaced mandibular second premolar and the adjacent first premolar and first molar served as the abutment teeth. Computerized Tomography (CT) images of the skull were taken and exported to solid modeling software, which were then transferred to the Finite Element Analysis (FEA) program. Teeth preparation of the abutment teeth was done with the occlusal reduction of 1.5 mm- 2 mm. The axio-gingival angles were rounded and core thickness was kept at 0.8 mm. Finish lines were positioned in enamel and pontic span set at 7 mm. The tapers were different in each model, the first being 14 degrees and the second 24 degrees. The connectors were 4 mm in height and 4 mm at width for both the models[9] and radius of curvature of gingival embrasure 0.9 mm. Static load of 100 N equal to the average bite force was applied to the middle of the pontic areas. Von Mises resolved stresses as well as principal stresses were recorded for each model at the connector as well as the abutment teeth. Data were tabulated and descriptive methods were used for statistical analysis of the data.

RESULTS:

Table 1 shows the maximum Von Mises stresses at the connector, first premolar and first molar for each model. The maximum Von Mises stresses for the first model with a taper of 14 degrees were 21 MPa at the connector, 5 MPa at the first premolar region and 2 MPa at the first molar region. The maximum Von Mises stresses for the second model with a taper of 24 degrees were 17 MPa at the connector, 5 MPa at the first premolar and 1.8 MPa at the first molar region.

Table 2 shows the maximum principal stresses at the connector, first premolar and first molar for each model. The maximum Principal stresses for the first model with a taper of 14 degrees were 16 MPa at the connector, 0.5 MPa at the first premolar region and 0.3 MPa at the first molar region. The maximum Principal stresses for the second model with a taper of 24 degrees were 14 MPa at the connector, 0.4 MPa at the first premolar and 0.3 MPa at the first molar region.

Table 1: Maximum Von Mises stresses in MPa

Taper	Connector	First Premolar	First Molar
14	21	5	2
24	17	5	1.8

Table 2: Maximum Principal stresses in MPa

Taper	Connector	First Premolar	First Molar
14	16	0.5	0.3
24	14	0.4	0.3

DISCUSSION:

The Law of Beams states that in a full ceramic fixed partial denture, tensile stresses are created in the gingival areas of connectors on application of occlusal load. Thus, the FPD is considered to be the weakest at the connector region and can lead to the formation of micro-cracks.[4,10,11] Considering the above mentioned statement, if design alteration is introduced at the region of the connector, stress could be reduced at its surface.[11] In a previous study, it was demonstrated by the use of Finite Element Analysis that stress concentration at the connector region could be reduced if the height of the connector was kept no less than 4 mm. Hence, a height and width of 4mm was taken for the connectors in our study.[12]

It has been observed that abutment teeth with higher taper angles during tooth preparation had a greater bulk of connector which led to increase in strength of the connector and the full ceramic FPD.[13] Therefore, the objective of this study was to determine the effect of taper of abutment teeth in the stress distribution of full ceramic 3 unit fixed partial dentures. In our study, the connectors were the weakest point in the FPDs, which is in agreement with previous studies.[9,14] Previous studies have demonstrated feasible single crown taper to be between 12 to 20 degrees.[15,16] Shillinburg et al.[17] have stated that the optimum taper for premolars should be 14 degrees for premolars and 22 degrees for molars. Therefore, in this study 14 degrees and 24 degrees tapers were used for premolars and molars,

respectively. Apholt et al.[18] have reported that FPDs require a force of 400 N for anterior region and 600 N for posterior regions. A vertical force of 100 N was used in our study, which is equivalent to the average bite force. Since, our study evaluates the distribution of stress instead of the load-to-failure of the FPDs, applied load is not a considerable factor of influence in our study.

In the present study the maximum Von Mises stress at the connector at 14 degrees taper was 21 MPa, whereas it was only 17 MPa at a taper of 24 degrees. Similar results were seen for Principal stresses, with a principal stress of 16 MPa at 14 degrees taper and 14 MPa at 24degrees taper. This reveals a decrease in the level of stresses at the connector with increase in the taper of the abutment teeth. Our results are in congruence with that of Geramipanah et al.[13], who have used a taper of 12 degrees and 21 degrees in premolar and molar, respectively.

CONCLUSION:

From the results of this study it can be concluded that increased taper may lead to decrease in stress at the region of the FPD connector. Since, taper of abutments is not the sole factor that determines the success of an FPD, further in-vitro studies as well as clinical trials are required to corroborate our results which would consider in addition to increased taper of abutments, other factors like connector size, design and position.

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