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Experimental and Numerical Study the Effect of Materials Changing on Behavior of Dental Bur (Straight Fissure) under Static Stress Analysis

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ABSTRACT

In this research, the objectives are achieved experimentally and numerically. The experimental works consisting tensile, flexural and torsion tests at room temperature (25^{o}C) for two materials; tungsten carbide and a novel that was eggshell powder mixing with polyester, to find a mechanical properties (Young's modulus and Poisson's ratio from tensile test, maximum bending stress from flexural test, maximum shear stress and modulus of rigidity from torsion test) of these materials.

A numerical static analysis of dental bur (straight Fissure) had been presented where a finite element model of straight fissure was built by programing method in ANSYS.14 software then it was exported as IGES file to ANSYS workbench.14 where in which the other steps of this analysis was completed.

Three sizes of straight Fissure bur were studied for two materials types where a comparison between tungsten carbide and a novel material that was eggshell powder was establish to investigate any material can withstand the same stress with lower stress values.

Main results show that the stresses value for a new material are less than the original manufacturing one and also the stress distribution of bur made from eggshell powder mixing with polyester was smoother than the tungsten carbide bur.

The experimental and numerical of maximum Von Mises stress percentage error as shown in **Table 3** are 13.33% and 7.06% for tungsten carbide and Eggshell mixing with polyester for size 1, respectively.

Key wards: straight fissure, dental bur, finite element, novel material, tungsten carbide, eggshell powder, stress distribution.

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1. INTRODUCTION

Tooth preparations for direct or indirect restorations are usually conducted with dental burs because their greater abrasion resistance and lower heat generation **[1]**. These rotatory instruments were empirically introduced in dentistry in the late19th century and have undergone improvements **[2]**. Dental burs are attached to a metal rod with wide range of sizes and shapes basically composed to do many functions like holing, drilling, resurfacing, etc...**[3]** The American Dental Association, the Centers for Disease Control and Prevention and other organizations clearly state that all dental instruments that penetrate or come into contact with dental tissues must be sterilized after each use to minimize cross contamination risks**[4]** and **[5]**. Cleaning and sterilization procedures of diamond bur are time consuming then it should be disposable or single patient use **[6]**. However in most dental offices dental burs are reused. Additionally manufacturers do not clearly indicate the bur durability so its discard is personal and subjective after tooth preparation, dental bur Surface is modified and if is used for another dental wear the smear layer may present distinct characteristics **[7]** and **[8]**. Some studies showed that smear layer thickness resulted by different abrasives and dentin topography after its removal affect bond strength to adhesive systems and resin cements **[9]** and **[10]**.

2. NUMERICAL ANALYSIS

In dental resurfacing, the dental bur was manipulated to traverse the bone surface for removal of a layer of material. Meanwhile, stress fields in the tooth are generated due to the interactions between the tooth material and the bur surface. When these stresses exceed a threshold value, the ultimate strength of the material, it is likely that the subsurface damage zone will be produced in the tooth **[11]**.

In this investigation, FEA was applied to model the dental resurfacing of feldspar porcelain using commercial software, ANSYS.14 (ANSYS Incorporated, USA). The dental resurfacing process was treated as a static problem for simplification, since the focus of this study was subsurface stresses and the damage zone formed under bur-tooth contact loads. The material was assumed to be isotropic and homogeneous **[11]**. The stresses and deformation produced were assumed to be within plane-strain conditions since the load and strain along the width of cut were nearly invariable during resurfacing. Three sizes of dental burs had been modeled where by using programing method each model was drew separately and then imported to ANSYS.14 then after finishing the dimensions preparations the models were exported to ANSYS workbench V.14. **Figure 1** shows cutter that had been modeled in this study.

The finite element model used in this study was high speed resurfacing dental bur. For the FEA geometric model, the dimensions were selected according to Saint-Venant's theory **[11]** and **[12]**.

Based on this FEA modeling, all stress components can be obtained. In particular, the Von Mises stress was of major interest.

The models that had been studied were with dimensions as shown in **Table 1[13]**. In this analysis we studied the effect of changing the original material of straight fissure bur (tungsten carbide) for all burs to second material type that was powder mixture of eggshell.

3. EXPERIMENTAL WORKS

3.1Dental Bur Materials Selection

Two materials had been used in this study for three sizes of resurfacing dental burs. First material type was tungsten carbide, where assumed to be an isotropic and homogenous material.

The second material type was powder of eggshell mixing with polyester.

3.2 Mechanical Properties of Dental Bur Materials

The mechanical properties for these materials had been calculated experimentally where specimens cutting to get the final dimensions flat specimens according to ASTM D638 **[14]**, all specimens were tested by using the universal testing instrument for tensile and flexural tests in the materials laboratories of the University of Technology as shown in **Figure 2**, to find the Young's modulus, Poisson's ratio and maximum bending stress, and circular specimens according to ASTM F1717 **[15]**, were tested by torsion test device as shown in **Figure 3**, to find modulus of rigidity and maximum shear stress. **Table 2** shows the mechanical properties of these materials.

4. LOADING AND BOUNDARY CONDITIONS

Digital dental bur model fixed from upper metal rode to simulate the fixation of headpiece. The fixed part subjected to displacement equal to zero in all directions x, y and z coordinates. The region of contact between both dental bur and tooth subjected to pressure equal to 0.2 MPa **[11]**.

After finishing the experimental results for each materials tests, Von Mises equation is used to calculate σ_{max} , and comparing these results with the numerical results of σ_{max}. as its shown in **Table 3**.

5. RESULTS

The stress distribution for the straight fissure bur can be considered as an important factor for designing it or any mechanical system so in this study the stress distribution was used to investigate the strength of bur under special load case. In **Figure 4** the effective stress distribution was shown for (size 1- tungsten carbide) where the left shape shows the counter bands of fissure and the right figure shows the isolines of stress distribution.

The same contours were shown in **Figure 5** but with bur made from eggshell powder. Results in these two figures shows that effective stress of eggshell bur is less than the effective stress of tungsten carbide by 0.6 MPa.

Figures 6 and 7 show the maximum effective stress for all burs sizes that made from tungsten carbide and eggshell powder, by comparing these two charts it's clear that Maximum effective stress in eggshell powder bur is less than its value in tungsten carbide bur. Maximum difference in effective stress value reach to 0.7MPa in size 2.

6. DISSCUSION AND CONCLUSIONS

We presented FEA modeling of dental resurfacing bur (straight fissure) under static analysis we focused our work on bur but in different side of view where the seeking for alternative biomedical materials can solve many problem.

In static analysis the stress distribution along a straight fissure is presented and from the contours of stress the position of maximum stress concentration had been shown where the point of junction between the neck end and head had the maximum value of stress due to sudden change in cross sectional area of bur where that is noticed for all studied sizes and for all materials types, so it is important to take into account this position during the designing of dental bur in order to reduce the concentration of stress.

As we mentioned previously that the maximum difference in maximum effective stress for all sizes not reach more than 0.7 MPa, in spite of that this value is not large value but it opens the door to introduce new materials types that could be used to manufacture a novel dental bur (straight fissure) made from eggshell powder which is cheaper than tungsten carbide.

The results of eggshell bur show smoother distribution along bur compared with the tungsten carbide bur, so based on stresses values of this study it is possible to introduce a new technic can improve the strength of dental bur by changing manufacturing material.

The experimental and numerical of maximum Von Mises stress percentage error as shown in **Table 3** are 13.33% and 7.06% for tungsten carbide and Eggshell mixing with polyester for size 1, respectively.

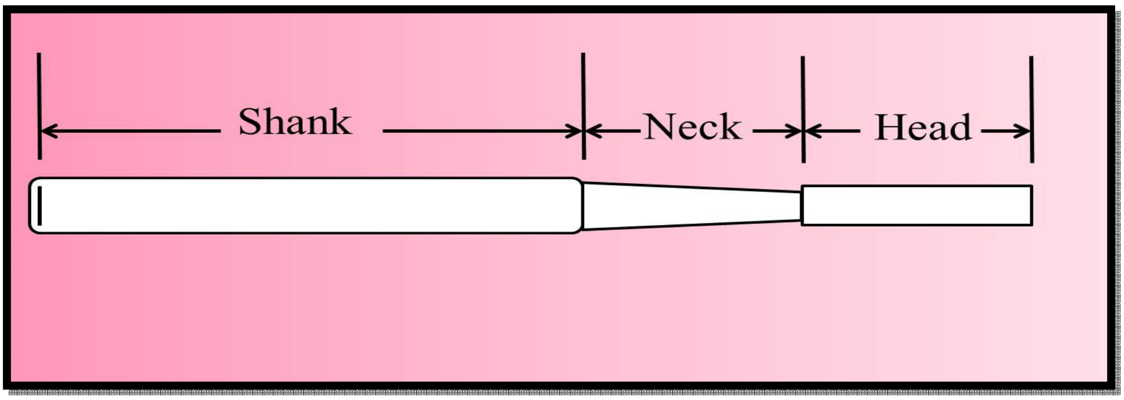


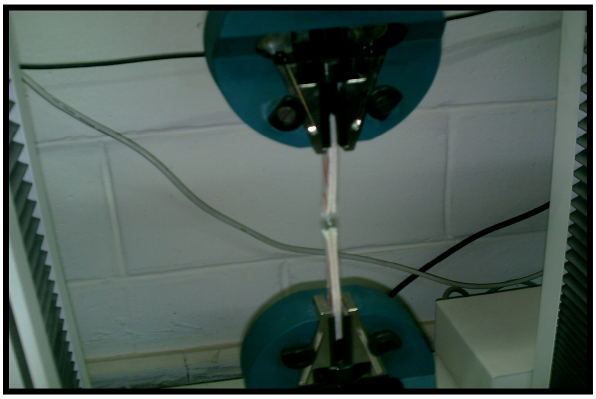
Figure 1: Parts of dental bur (straight Fissure).

Table 1: Models dimensions.

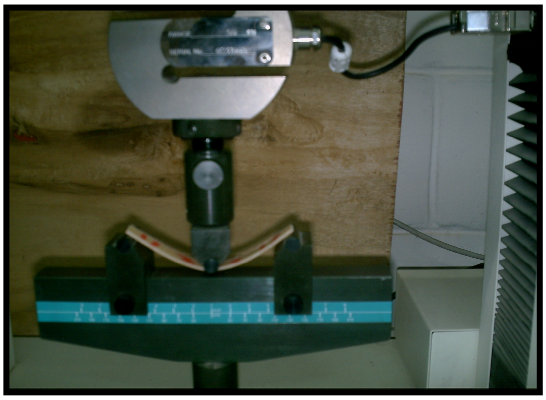
Type	Numerical Code	Shank Length(mm)	Head Diameter(mm)	Head Length(mm)
Model 1	56	19	0.8	3.8
Model 2	57	21	1	4.2
Model3	58	23	1.2	4.5

Table 2: Material properties.

Material	Young's modulus (GPa)	Poisson's ratio	Modulus of rigidity (GPa)	Maximum static bending stress (MPa)	Maximum static torsion shear stress (MPa)
Tungsten carbide	557	0.24	225	80	32.4
Eggshell mixing with polyester	16.1	0.29	6.25	66.5	28.9



a-Tensile test.



b-Flexural test.

Figure 2: Tensile and flexural static tests device.

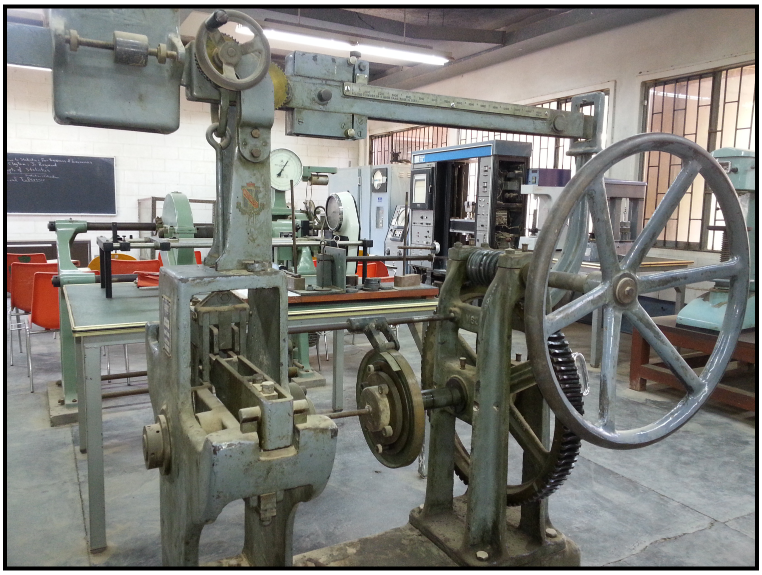


Figure 3: Torsion static test device.

Table 3: Maximum Von Mises stress for each materials of dental bur for size 1.

Material	Max. Von Mises stress experimentally(MPa)	Max. Von Mises stress numerically(MPa)	Percentage error (%)
Tungsten carbide	**31.45**	**27.749**	**13.33**
Eggshell mixing with polyester	**29.22**	**27.291**	**7.06**

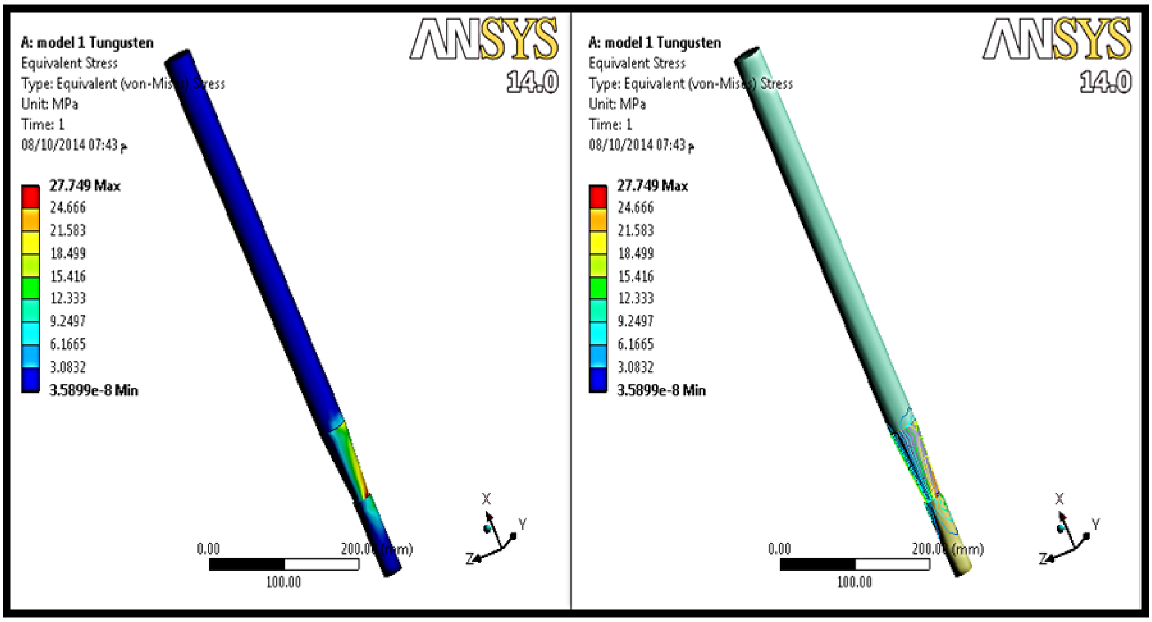


Figure 4: Distribution of effective static stress analysis for (size 1) mode for tungsten carbide.

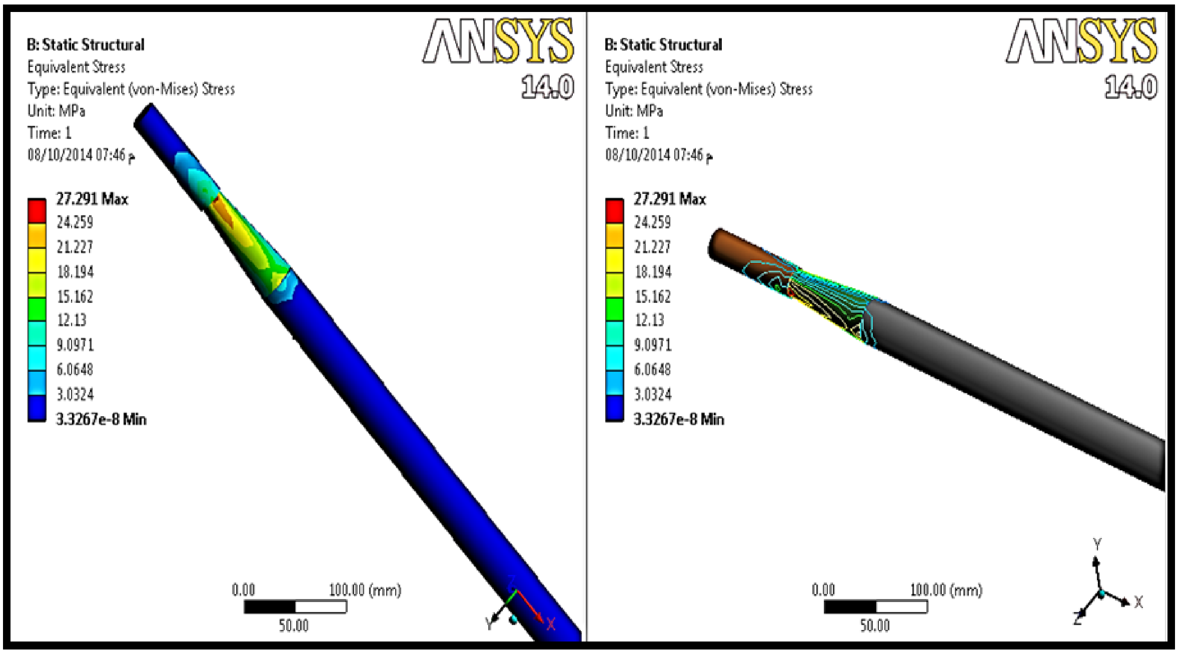


Figure 5: Distribution of effective static stress analysis for (size 1) mode for eggshell powder mixing with polyester.

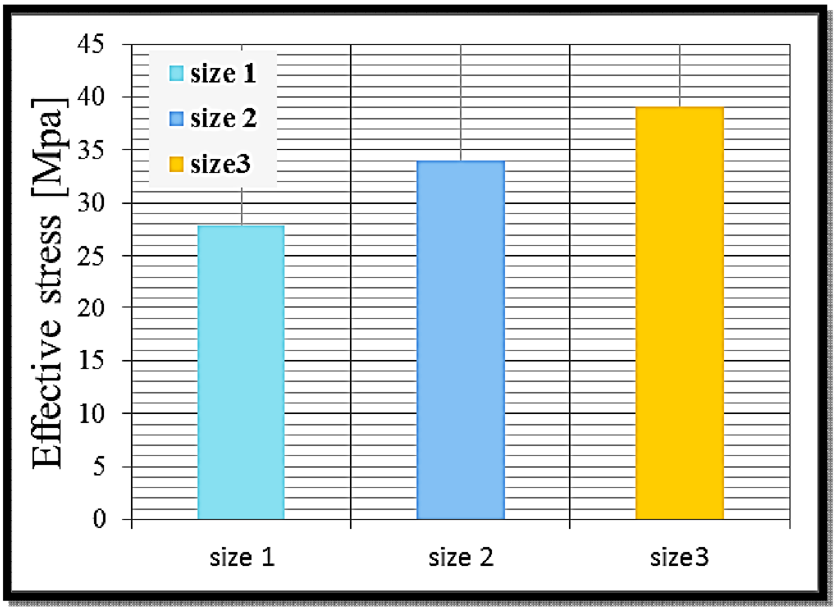


Figure 6: Maximum effective stress for all models – static analysis- tungsten carbide.

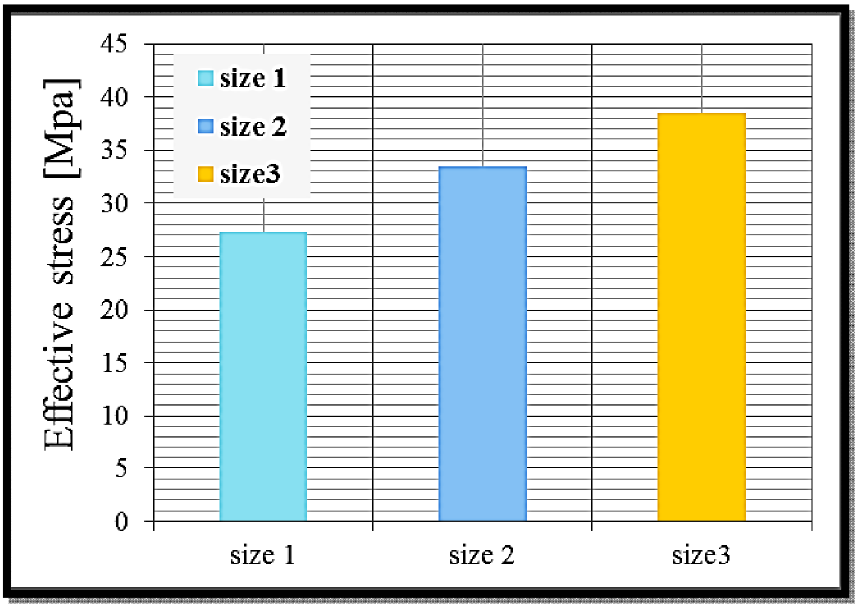


Figure 7: Maximum effective stress for all models – static analysis- eggshell powder mixing with polyester.

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