Experimental and Numerical Stress Distribution of Molar Teeth with Different Type of Fillings

Bashar Owaid Bedaiwi **Zaineb Wared Matab**
Mechanical Engineering Department, College of Engineering
Al-Mustansiriyah University
phdbashar@yahoo.com z.oo35@yahoo.com

Abstract

The human body poses the most important aim for many researchers. In nowadays, the science complex required the involvement of many resources and the coordinated team work of doctors, engineers, and other from the specialists. In the case of dental medicine, due to the nature of teeth material, their dimension and geometrical position, very important problems, like cavities that led to tooth losses. In this study, both the Experimental methods as well as the numerical finite element method have been used to analyze the stress within human teeth under forces similar to those that usually occur during chewing process with different type of food in experimental work. It was manufactured a device Resembling chewing process with vertical movement by converting circular movement into reciprocating. And used DAQ system (strain gauge sensor, DAQ and LABVIEW program) to measure the stress and strain resulted from tooth during the mastication process. Models of Natural lower first molars teeth were collected. All the teeth were cleaned from the soft tissue and stored in saline at room temperature. The teeth were randomly divided into two experimental groups according to the treated cavities shape (class I and class II) each class restored with two type of dental fillings material (Nanohybrid composite and Microhybrid composite), and then strain gauge was bonded at a buccal surface of tooth used. Their installed in acrylic jaws and applied different vertical loads. With used various morsels with different elastic modulus. The stress was calculated at the crown. In numerical 2D model of teeth were created by software Auto CAD (V.14) using wheeler 's data were transfer to ANSYS mechanical APDL (V. 16), subjected load at model similar at that applied at the Experimental work. Class I exhibited the highest stresses compared with class II, in two case Nanohybrid bear stress higher than microhybrid composite. At class I the stress at Nanohybrid is higher than Microhybrid for all morsels by rate (12.96%, 21.48%, 41.8%, 16.56%, 16.86% and 15.74%) at (E_1, E_2, E_3, E_4, E_5 and E_6) respectively, and the stress at Nanohybrid is higher than Microhybrid by almost (36.67%, 45.69%, 47.89%, 34.21%, 41.2% and 165.01%) respectively at the same morsels used at class II.

Keywords: Molar tooth, composite dental materials, Stress Analysis.

1. Introduction:

To reduce loss of tooth tissue and to improve biomechanical results, dental filling restorations are good treatment choices for cavities in posterior teeth. Dental filling composite simply replaces missing tooth structure, without doing anything to reinforce the remaining structures. Stress concentrations can manifest themselves in various forms of failures **[1]**. It is can be used on molars requiring a class II restoration instead amalgam. Because it is known that class II may increase the ability to fracture **[2]**. In 1954 (M.B. Mahler and D.Sc Peyton)**[3]** studied photoelasticity as a research technique for analyzing stresses in dental structures and natural tooth, This method of analysis was shown to be particularly applicable to dental problems because of the irregular shapes of dental structures. In 2003 (Beata Dejak at. el.) [4] analyzed the stresses induced in a mandibular molar during clenching and chewing of morsels with various elastic moduli using FEA. At morsels of high elastic moduli resulted in maximal equivalent stresses within occlusal enamel and at morsels of low elastic moduli the stress concentration was located in the cervical region of the lingual side of the mandibular molar. In 2008 (Beata Dejak at. el) [5] compare strength of mandibular molars restored with composite resin inlays to those restored with ceramic inlays, according to the Mohr-Coulomb failure criterion, and to analyze contact stresses in cement-tooth adhesive interfaces of these inlays. Used 3D FEA At the adhesive interface between the cement and tooth around the ceramic inlays, contact tensile and shear stresses were lower than around the composite resin inlays. In the cervical enamel surrounding the proximal surface of the inlays, the stresses exceeded the tissue strength. Mohammed in 2011[**6**] investigated of stress at the molar tooth treatment with different filler material, amalgam, composite and gold, used finite element analysis with ANSYS software. The result is indicating that the amalgam is the best filler material for molar tooth treatment. Claudia Bratosin at. el 2014 [7] determined the stress and strain distributions in bone structure – primary molar – restorative material assembly by finite element method, the method used for obtaining the 3D models consisted in processing with special software (Mimics) the tomography images acquired with the aid of a CT scanner and evaluate the contact pressure at the interfaces bone – molar and molar – restorative when a load of 120 N has been applied over all the upper surface area of model. The maximum values of the stresses of the composite resin used as dental filling are 50% smaller than the stresses in the case of Gic Fuji IX material, the contact pressure on the interface molar-composite resin is 53.8% smaller in comparison with dental filling consisting of Gic Fuji IX material. Iqbal musani et. al. [8] Studied the biomechanical stress analysis of mandibular first permanent molar, restored with amalgam and composite resin, it is concluded that the amalgam is a better restored material in stress distribution.

2. Experimental work:

2.1 Test rig

In this study the mechanism to masticatory simulators is manufactured as shown in Figure (1), to get vertical reciprocating movement to determine stress and strain at molar tooth. It consists of frame, Crank wheel, connecting rod, sample basement, clamps or jaws, (load cell and weight indicator) and data Acquisition System that consist of: strain gages (foil type, 120 Ω, gage factor=2) bounded on the test molar tooth model and transmitted bars, Wheatstone bridge, DAC and Labview program as software. With the mandible in motion, the maxilla must realistically be fixed.

2.2 Preparation of models:

Natural four lower first molars teeth were collected. All the teeth were cleaned from the soft tissue and stored in saline at room temperature. The teeth were divided into two experimental groups (class I and class II) each group restored with two type of dental fillings material. The test is used food a specimen with different modulus of elasticity, it tested by tensile test which performed according to ASTM D638 [9] to get the mechanical properties from it, as shown in table (1).

Two type of composite fillings material is used, the Nanohybrid composite dental fillings and Microhybrid composite dental fillings. When the tooth is restored, the surfaces of the cavities treated with acid gel for 30 seconds, then washed with air-water spray for 15 seconds and dried by compressed air. Single bond adhesive was applied and cured for 10 seconds using light cure unite, then the cavities were filled with light curing hybrid composite. Every increment was cured for 40 seconds using visible light cure unit. The restorations were finished and polished. Then bond strain gauge at the buccal, when mechanism is worked the strain gauge deformation, and this signal transfer by DAQ to computer to read by Labview program. Figure (2) shows the preparation of models (Dental fillings).

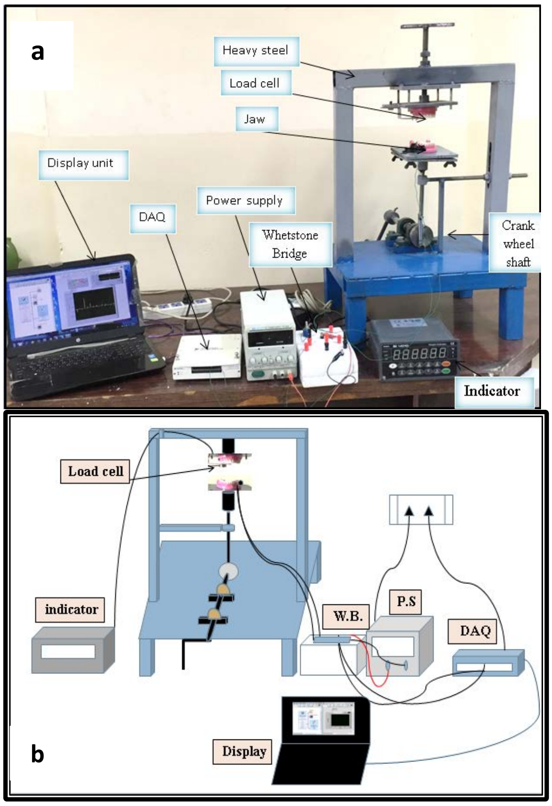


Figure 1: a. Overall Test Apparatus (b) Schematic of test rig

Table 1: Mechanical Properties of Material used as Morsels

Material	Elastic modulus (Mpa)
Morsels 1 (E_1)	4.5
Morsels 2 (E_2)	4
Morsels 3 (E_3)	3.342
Morsels 4 (E_4)	2
Morsels 5 (E_5)	1.5
Morsels 6 (E_6)	1

2.3 Test procedure:

The following procedures were followed:

1. The model is prepared by filled and bonded strain gage as explain already.
2. The model of first molar tooth is fixed in place at the jaw acrylic.
3. Turn on the power supply voltage.
4. Turn on the switch of indicator.
5. Connect the DAQ with a computer.
6. The test was started when The lever is moved manually, the circular movement of the wheel shaft transfer by connecting Rod to reciprocating movement at the mandible, while the upper jaw fixed, similar to the process of chewing for humans. The material is placed between the jaws similar material for the food and to shed mastication force to chew food between the jaws. Determine by force sensor (load cell +indicator).

7. The molar tooth is loaded so strain gauge is affected deformation and this explaining from DAQ through the reading by lab view program.
8. After few cycle, stopped the motion, and save data at computer.
9. The signal resulting from DAQ, it can be observed from the values of varying amounts, so used RMS (root mean square) as a statistical measure at this case to get one value, it is especially useful when the positive and negative values differ, the value result turn by calibration to load then from it get the stress and strain.

Figure 2: Preparation of Models (Dental Fillings)

3 Mechanical tests:

3.1 Tensile Test

The tensile test is performed according to ASTM D638 [9]. Three samples for each specimen was mentioned as shows in figure (3). It is tested at a cross head speed (strain rate) of (0.1mm/min) until break the specimen occur

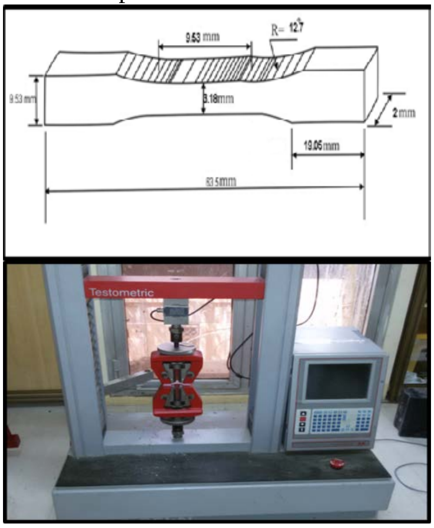
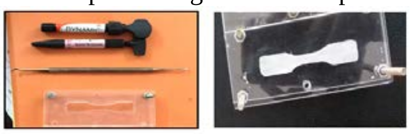


Figure 3: Schematic Specimen for Standard Specimen of Tensile Test and tensile test device

3.2 Preparation of Specimens

Acrylic mold which has reduced surface defect was used to prepare tensile specimens as shows in figure with dimension from ASTM 638. the mold was fatted textured Vaseline to prevent the adhesion of sample material in the mold, then pour the filling Arrange mold with glass to prevent the contraction of the material and take out the excess and to obtain a flat surface, Then hardening material using light Cure device, as shows in figure(4). After the Specimen was removed from the mold they were examined for any surface defect on the surface and edges by naked eyes. Sharp and irregular edges were removed by using abrasive paper. Samples were stored in plastic bag at room temperature.



a. Mold of Tensile Specimen and Case of Material b. Mold Filled with the Material

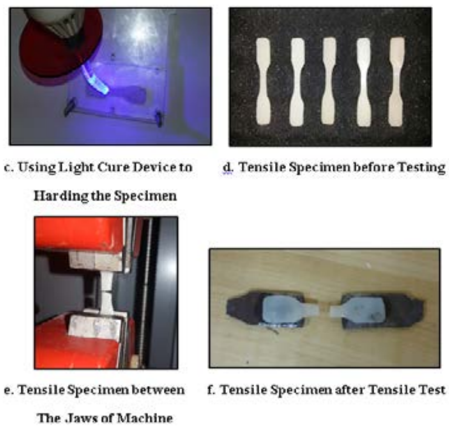


Figure 4: Preparation of Specimens

3.3 Compressions Test

The compression test is performed according to ASTM D695 [10] by using the same tensile machine at across speed of (0.1mm/min) until the break of the specimen occurs. Figure (5) shows the standard specimen of compression test and compression test device.

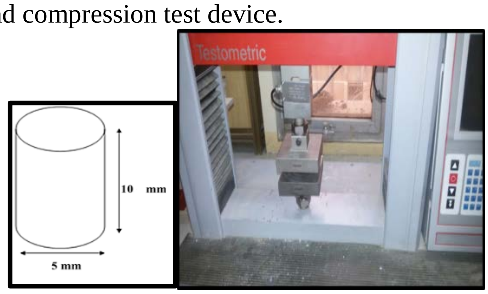


Figure 5: the standard specimen of compression test and compression test device

3.4 Preparation of Specimens

The same procedures followed in tensile sample preparation, as shown in figure (6).

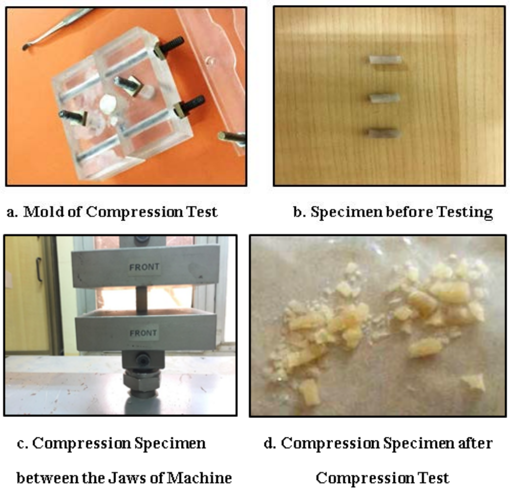


Figure 6: Preparation of Specimens

The results obtained from tensile and compressive tests of specimen are listed in table (2)

Table 2: Result of Tensile Test and Compressive Test

Mechanical properties	Tensile test		Compression test	
	Nanohybrid	microhybrid	Nanohybrid	microhybrid
Yield stress Mpa	6.643	8.03	18.609	14.406
Ultimate stress Mpa	32.35	38.36	90.5663	70.86
Yield deformation mm	0.0467	0.04	0.2763	0.195
Yield strain	.00292	0.0025	2.736	1.95
Young modulus(E) Mpa	1830.618	2624.735	1102.1503	1342.119
Passion ratio (ν)	0.3	0.44	0.355	0.142

4. Numerical work

ANSYS mechanical APDL version (16) is used, a model of two dimensions finite element of mandible first molar tooth is built according to the true geometrical dimensions, and the dimensions of the first molar tooth take from wheelers dental Anatomy text book]. By using Auto CAD (V14) program, the molar tooth was plotted by measuring and recording its (x, y) dimensions. Finally, the molar tooth geometry to (ANSYS-16) mechanical APDL was produced, with element solid (183). It was applied to study the stress on molar tooth with two type of cavities (class I and class II) at both filling (Nanohybrid and Microhybrid). The number of element used for this work models are (4751), while the number of nodes is (14843), as shown in figure (7).

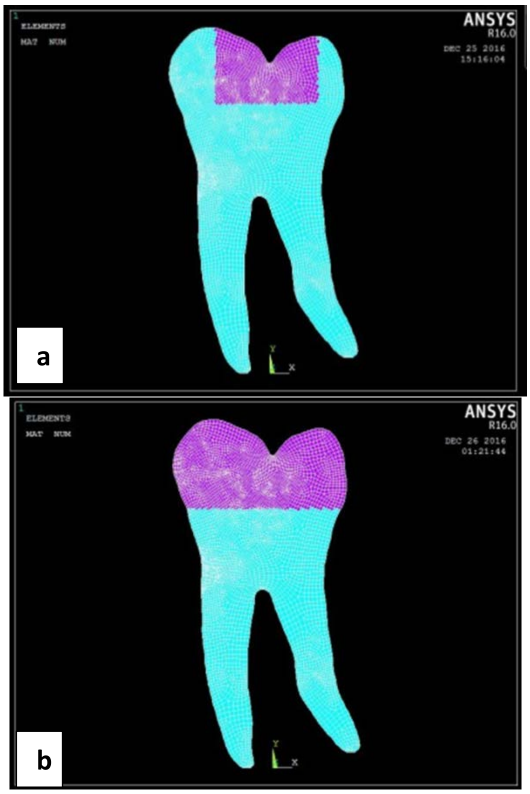


Figure 7: Meshing of Tooth Model with Cavities **(a)**Class I, **(b)** Class II

5. Results and Discussion

The experimental results shown in Figs. 8 and 9 indicate that the effect of load increment on the stress at molar tooth for the class I cavity. It can be seen that the filling material in class I which was (Nanohybrid composite and Microhybrid composite), with used various morsels different in elastic modulus. The load increased up to (320, 160, 140, 120, 75 and 70) N for different food elasticity (E_1, E_2, E_3, E_4, E_5 and E_6). For Nanohybrid the stress of E_1 is increased by (85.2%), (83.72%), (97.65%), (240.37%) and (151.80%) more than (E_2, E_3, E_4, E_5 and E_6), and with Microhybrid the stress of E_1 is increased by (99.16%, 130.62%, 103.95%, 252.13%, 158%) more than other morsels respectively. Table (3) shows the maximum results of the class I for Nanohybrid and Microhybrid.

Nanohybrid bear stress higher than microhybrid composite. At class I the stress at Nanohybrid is higher than Microhybrid for all morsels by rate (12.96%, 21.48%, 41.8%, 16.56%, 16.86% and 15.74%) at (E1, E2, E3, E4, E5 and E6) respectively, as shown in fig.10.

Table 3: Results of the class I for Nanohybrid and Microhybrid

Morsels	Maximum load (N)	Nanohybrid		Microhybrid	
		σ (Mpa)	Ɛ (Micro)	σ (Mpa)	Ɛ (Micro)
E1	320	3.1672	243.8341	2.8037	295.7330
E2	160	1.7101	131.6541	1.4077	148.4871
E3	140	1.7239	132.7213	1.2157	128.2367
E4	120	1.6024	123.3651	1.3747	145.0031
E5	75	0.9305	71.6365	0.7962	83.9814
E6	70	1.2578	96.8334	1.0867	114.6306

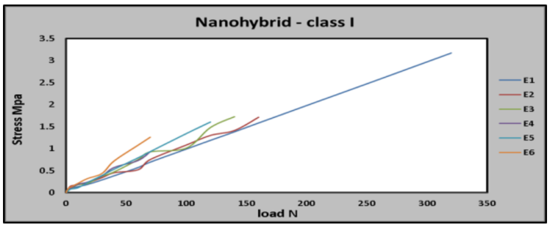


Figure 8: Stress for Microhybrid composite class I for different morsels

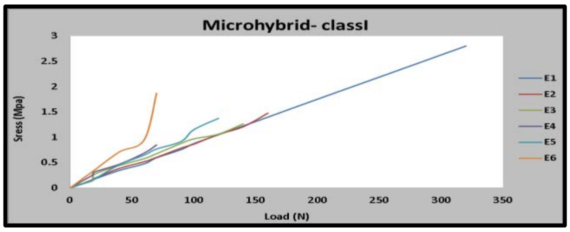
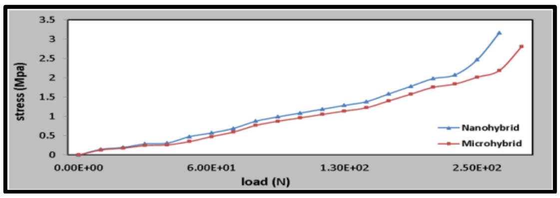


Figure 9: Stress for Microhybrid composite class I for different morsels



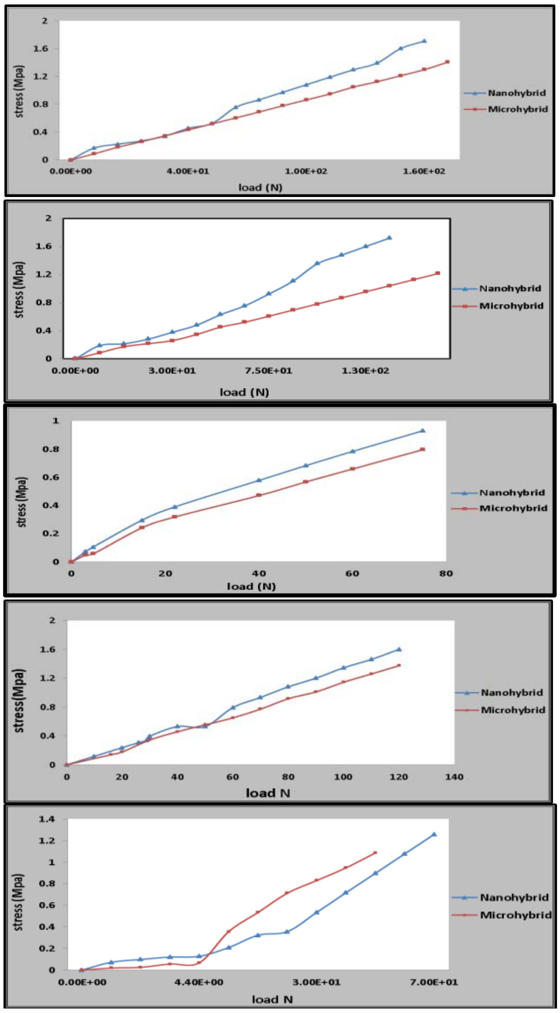
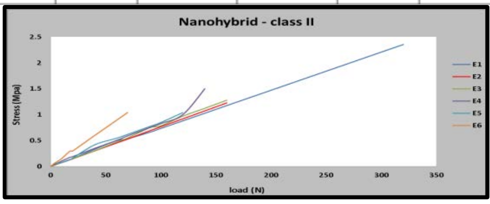


Figure 10: Stress for Nanohybrid and Microhybrid composite at class I cavity for different morsels with (E1, E2, E3, E4, E5 and E6) respectively

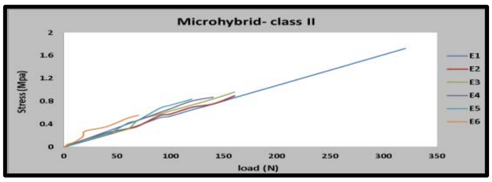
Figure (11) shows the relationship between load increments with stresses at molar tooth filled with Nanohybrid and Microhybrid dental fillings. The load increased up to (320, 160, 160, 130, 120 and 70) N for (E1, E2, E3, E4, E5 and E6). It can be noted from figure that increases in load causes increasing in stress. Also, the stress of tooth with class II cavity filled in Nanohybrid at E1 is increased by (91.67%, 88.29%, 101.34%, 161.54% and 125.88%) more than it at (E2, E3, E4, E5 and E6) respectively, and at Microhybrid the stress at E1 is increased by (104.33%, 103.77%, 97.74%, 170.23% and 338.01%) higher than of it at (E2, E3, E4, E5 and E6). The stress at Nanohybrid is higher than Microhybrid by almost (36.67%, 45.69%, 47.89%, 34.21%, 41.2% and 165.01%) respectively at the same morsels used at class II. Table (4) shows the maximum results of the class II for Nanohybrid and Microhybrid.

Table 4: Results of the class II for Nanohybrid and Microhybrid

Morsels	Maximum load (N)	Nanohybrid		Microhybrid	
		σ (Mpa)	Ɛ (Micro)	σ (Mpa)	Ɛ (Micro)
E1	320	2.3544	229.6221	1.7227	181.7551
E2	160	1.2283	119.7951	0.8431	88.9479
E3	160	1.2503	121.9462	0.8454	89.1919
E4	130	1.1693	114.0441	0.8712	91.9213
E5	120	0.9002	87.8031	0.6375	67.2584
E6	70	1.0423	101.6537	0.3933	41.4939

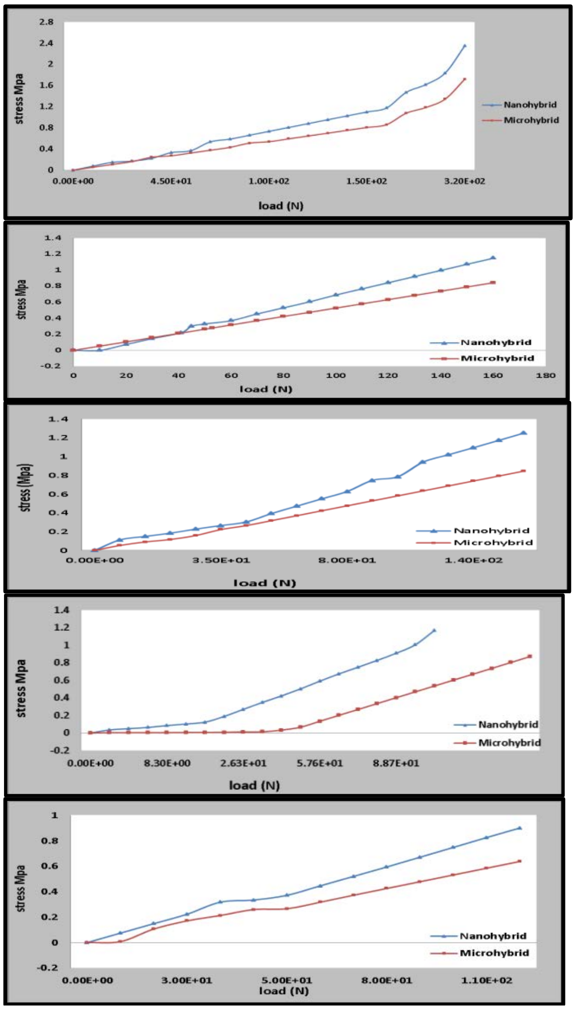


a



b

Figure 11: Stress at molar tooth with class II for different morsels of a. Nanohybrid b. Microhybrid



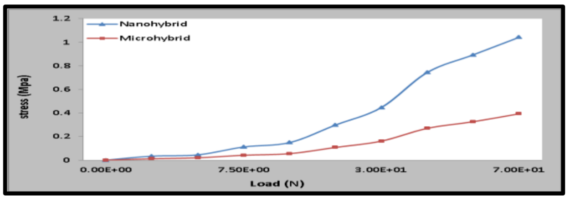


Figure 12: Stress for Nanohybrid and Microhybrid composite at class II cavity for different morsels with (E1, E2, E3, E4, E5 and E6) respectively

Figure (13) shows the contours plot of the stress of composite filling material at class I and class II.

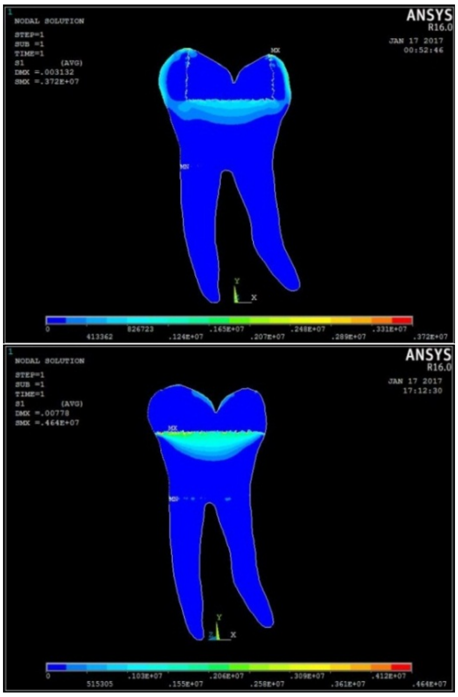


Figure 13: Contours of maximum stress at molar tooth of class I and class II cavity

In order to clarify the difference between the experimental and numerical results of stresses for Nanohybrid and Microhybrid at class I and class II, the result are listed in tables below.

Table 5: Maximum stresses of class I at (Nanohybrid and Microhybrid) in experimental and Numerical

load (N)	Stress (Mpa) at Nanohybrid		error %	Stress (Mpa) at Microhybrid		error %
	experimental	Numerical		experimental	Numerical	
0	0	0	0	0	0	0
20	0.55	0.505	8%	0.4596	0.462	1%
50	1.38	1.44	4%	1.286	1.15	10%
100	2.76	2.51	9%	2.298	2.29	0%
130	3.59	3.72	3.60%	2.987	2.8	6%
200	5.53	4.75	14%	4.59	4.57	4%
320	8.86	8.13	8%	7.35	7.3	6%

Table 6: Maximum stresses of class II at (Nanohybrid and Microhybrid) in experimental and Numerical

load applied N	Stress (Mpa) at Nanohybrid		error %	Stress (Mpa) at Microhybrid		error %
	experimental	Numerical		experimental	Numerical	
0	0	0	0	0	0	0
20	0.31	0.259	16%	0.169	0.146	14%
50	0.7	0.712	2%	0.424	0.384	9%
100	1.587	1.43	9%	0.84	0.76	9%
130	2.3	2.14	6.00%	1.1	1.04	5.40%
200	3.17	2.85	10%	1.69	1.62	4%
320	5.07	4.64	8%	2.71	2.63	3%

7. Conclusions

1. Stresses levels are higher in molar tooth filled with Nanohybrid than it with Microhybrid at class I and class II.
2. When using same filling material, during mastication the different morsels effect on stress at molar, Stress located on buccal surface was clear. At class I, the maximum stress at molar model with E1 is higher than E6 by rate 151.8 % at Nanohybrid, and 158% at Microhybrid. At class II, the maximum stress at molar model with E1 is higher than E6 by rate 125.88 % at Nanohybrid, and 338.01% at Microhybrid, where high elastic moduli cause stress concentration was located in the cups region. Mastication of low elastic moduli cause stress concentration was located in the cervical region.
3. In tooth model for both composite filling material the stress at class I is higher than from it at class II..

8. References

[1]. Shillingburg, H.T., et al. (1997), **Fundamentals of Fixed Prosthodontics, ed,** Learning. **10**: p. 40.

[2]. Sandu, L., F. Topala, and S. Porojan (2011), **Stresses in Cast Metal Inlays Restored Molars**. World Academy of Science, Engineering and Technology. **5** :p. 2142-2145.

[3]. Mahler, D. and F. Peyton (1955), **Photoelasticity as a research technique for analyzing stresses in dental structures.** Journal of Dental Research. **34**(6): p. 831-838.

[4]. Dejak, B., A. Młotkowski, and M. Romanowicz (2003), **Finite element analysis of stresses in molars during clenching and mastication.** The Journal of prosthetic dentistry. **90**(6): p. 591-597.

[5]. Dejak, B. and A. Mlotkowski (2008), **Three-dimensional finite element analysis of strength and adhesion of composite resin versus ceramic inlays in molars**. The Journal of prosthetic dentistry. **99**(2): p. 131-140.

[6]. Mohammed W. Al-Hazmi (2011), **Finite Element Analysis for Molar-Tooth Treatment with Different Filler materials**. Mechanical Engineering Department, Vol. 4, No.2, pp. 37-53.

[7]. Claudia Bratosin at. el. (2014), **the stress and strain distributions in bone structure – primary molar – restorative material assembly by finite element method**.

[8]. Musani, I. and A. Prabhakar (2010), **Biomechanical Stress Analysis of Mandibular First Permanent Molar; Restored with Amalgam and Composite Resin: A Computerized Finite Element Study.** International Journal of Clinical Pediatric Dentistry. **3**(1): p. 5.

[9] Standard, A.(2003), **Standard test method for tensile properties of plastics.** ASTM International. Designation: D. **638**.

[10]. International, A. (2010), **Standard Test Method for Compressive Properties of Rigid Plastics.** ASTM International.

توزيع الإجهاد تجريبيا وعدديا لأسنان الضرس مع انواع مختلفة من الحشوات

بشار عويد بديوي **زينب وارد متعب**

قسم الهندسة الميكانيكية / الجامعة المستنصرية

الخلاصة

جسم الإنسان يشكل الهدف الأكثر أهمية لكثير من الباحثين. في الوقت الحاضر، العلوم المعقدة تتطلب مشاركة العديد من الموارد والعمل الجماعي المنسق بين الأطباء والمهندسين، وغيرها من المتخصصين. خاصة في حالة طب الأسنان، ويرجع ذلك إلى طبيعة المواد الأسنان، الموقع والابعاد الهندسية، من المشاكل الهامة جدا، تسوس الأسنان والتي أدت إلى خسائر الأسنان. في هذه الدراسة، تم استخدام كل الأسلوب العملي فضلا عن طريقة العناصر المحددة العددية لتحليل الإجهاد داخل الأسنان البشري تحت قوى مشابهة لتلك التي تحدث عادة أثناءالمضغ مع انواع من الطعام المختلف في معامل المرونه. في الجانب العملي تم تصنيع جهاز مشابة عمليةالمضغ في حالة الحركة العمودية من خلال تحويل حركة دائرية إلى الترددية. ويستخدم نظام نقل البيانات وبرنامج لاب فيولحساب الاجهاد من خلال تسليط قوة عمودية على الأسنان أثناء عملية المضغ. تم جمع نماذج من الأسنان (الضراس الاول في الفك السفلي) الطبيعية. تم تنظيف جميع الأسنان من الأنسجة اللينة وتخزينها في المياه المالحة في درجة حرارة الغرفة. تم تقسيم الأسنان إلى مجموعتين وفقا للشكل التجاويف (الدرجة الأولى والدرجة الثانية) والمعالجة مع اثنين من نوع الأسنان مواد حشو ثم قياس الاجهادعلى سطح السن, من خلال لصق متحسس الانفعال على سطح السن وتثبيت السن في فك الاكريليك وتطبيق الأحمال الرأسية المختلفة. في الجانب التحليل العددي تم تحليل الاجهادات باستخدام برنامج عددي. شكل الفجوة الاول أظهر اجهاد اعلى من شكل الفجوة الثانية. في كلا الحالتين النانو يظهر اجهادات اعلى من المايكرو. في الفجوة الاولى النانو اعلى من المايكرو لكل انواع الطعام المستخدم بنسبة (12.96%, 21.48%, 41.8%, 16.56%, 16.86% و15.74%) على التوالي. الاجهاد في النانواعلى من المايكرو بنسبة (36.67%, 45.69%, 47.89%, 34.21%, 41.2% و 165.01%) على التوالي لكل انواع الطعام المستخدمة في حالة الفجوة الثانية.