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EVALUATION OF WEAR RESISTANCE AND BOND STRENGTH BETWEEN DIFFERENT TEETH MATERIALS AND ACRYLIC DENTURE BASE MATERIALS (COMPARATIVE IN VITRO STUDY)

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ABSTRACT

Background: This study aimed to compare the bond strength of an acrylic denture base with three types of artificial teeth materials: Nanohybrid composite artificial teeth (NHC), acrylic resin, and the PEEK denture teeth veneered with HIPC composite resin, and the wear resistance of these three types of denture teeth.

Materials and Methods: Twenty-four bonded teeth were categorized into three groups. Group I: Acrylic resin teeth bonded to a conventional denture base. Group II: Nanohybrid composite teeth bonded to a conventional denture base. Group III: Polyether Ether Ketone core veneered with High-Impact Polymer Composite teeth bonded to a conventional denture base. Wear resistance and bonding strength between these teeth types and the acrylic resin denture base were evaluated.

Results: there was a significant difference between the three Groups after the wear stimulation test. Group III recorded the highest wear resistance followed by Group I and the lowest wear resistance was in Group II, Also there was a significant difference between the three Groups after a shear force was applied until samples debonded. The highest shear dislodgment force was recorded with Group I followed by Group II while the lowest shear dislodgment force was in Group III.

Conclusion: Group I shows the highest bond strength with acrylic resin denture base and moderate wear resistance Group II shows moderate bond strength with acrylic resin and lowest wear resistance while Group III shows the highest wear resistance and the lowest bond strength.

KEYWORDS: Wear resistance, Bond strength, Teeth material, acrylic resin, denture base

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INTRODUCTION

Artificial prosthetic denture teeth play an important role in restoring oral function, aesthetics as well as mastication and speech [1]. Supporting the facial structures and improving the psychological benefit of the patient is also an important role of artificial teeth. [2] These prosthetic teeth are made from various materials, each material offers special properties and advantages, and to improve the teeth' properties and function many modifications have been done [3,4]

Acrylic resin, porcelain, Polyetheretherketone (PEEK), and different types of composite teeth, are used as artificial denture teeth for complete and partial dentures, each material has its advantages, disadvantages, and character. [4].The material choice depends on the budget of the patient, the patient's needs, and the clinical situation [5]

Porcelain denture teeth were the first tooth materials used in dentistry and although they have many advantages like excellent wear resistance, their color provides good aesthetics and preserves the vertical dimension of occlusion they are rarely used as denture teeth for complete and partial dentures because their composition is not similar to that of acrylic resin teeth which make these materials bond with acrylic resin denture base by mechanical bond not with chemical bond so they have poor bond strength with acrylic resin, they are harmful to the underlying structure as well as they have to click sound and they are difficult to be adjusted [6,7]

The most common and popular material used for artificial denture teeth in complete and partial dentures is acrylic resin tooth material because its low cost and lightweight can be accepted by many patients [8,9,10]. Also, one of the most essential functions of acrylic resin teeth is easily adjusted and easy to repair [9], however, this tooth materials types have many disadvantages, low thermal conductivity, and surface microporosity as well as low wear resistance which cause a loss in the vertical dimension of occlusion and affect the masticatory efficacy so these disadvantages make the acrylic resin teeth material types to be replaced more frequently [8,10]

Composite resin artificial denture teeth are made of different matrices of resin and filler they show a better color appearance than acrylic resin and also show greater shock-absorbing capacity and enough bonding to the denture base [11,12]

Composite resin teeth materials have many types, the micro-filled composite shows the best esthetics, the micro-hybrid composite shows more strength, the High Impact Performance Composite(HIPC) shows superior mechanical strength and good flexure strength when compared with the traditional types and. The new nano-hybrid composite provides superior properties, a UDMA matrix, three distinct fillers, and PMMA clusters incorporated into its structure. Each filler type offers specific benefits. The first filler type (inorganic densified silanized SiO2), is utilized to reinforce the matrix and enhance the hardness of the materials. The second filler type (silanized SiO2 nanoparticles), enhances the composite structure's strength and reduces wear on the opposing tooth structure while the third filler type, inorganically filled DMA polymer, is beneficial for reducing polymerization shrinkage stress (13,14)

Polyetheretherketone (PEEK) is a distinctive polymer material recently introduced to dentistry. It offers superior mechanical properties and is lighter than traditional materials. The modulus of elasticity of this material is similar when compared to human bone tissue this similarity provides a damping effect and decreases stress shielding for PEEK restoration [15,16]., the stiffness of this material is not enough to withstand loads-bearing and this is one of its disadvantages as it leads to a high risk of fracture by the addition of glass fibers or carbon fibers to the PEEK gives it a stronger mechanical strength and stability than other dental materials [17,18] other

disadvantages of PEEK are The weak aesthetic when compared to other dental materials and the improvement of this aesthetic problem PEEK must be veneered with composite resins and can be used as crown or denture teeth [19,20] and the inert surface of PEEK makes it difficult to bond with different dental materials and need to undergo different surface treatment [21,22,23].

This study aimed to compare the bond strength of an acrylic denture base with three types of artificial teeth materials: nanohybrid composite artificial teeth (NHC), acrylic resin, and the PEEK denture teeth veneered with HIPC composite resins. Additionally, the study compared the wear resistance among these three types of denture teeth.

MATERIALS AND METHODS

Twenty-four bonded teeth to conventional acrylic resin denture base block samples were constructed and categorized into three groups according to bonded teeth type

Group I: Acrylic resin teeth bonded to conventional acrylic resin denture base block

Group II: Nanohybrid composite teeth (NHC) bonded to conventional acrylic resin denture base block

Group III: Polyether Ether Ketone (PEEK) core veneered with High-Impact Polymer Composite (HIPC) teeth bonded to conventional acrylic resin denture base block

Tooth fabrication:

Three types of teeth were used in this study: Acrylic resin teeth, Nanohybrid composite teeth, and PEEK core veneered with HIPC composite resins.

Eight upper 2nd premolar teeth from an acrylic resin teeth sheet (Vita- -Pan Acrylic Teeth, Vita Bad Sackingen, Germany) were picked to be used for this study while for PEEK core and NHC teeth, an upper 2nd premolar tooth was scanned by the 3D dental scanner (Identica hybrid; MEDIT corp., Seoul, Korea), eight premolars were milled from NHC block (CAMouflag®, United States), and eight premolars were milled with prefabricated PEEK blank (breCAM.BioHPP Discs; Bredent, Senden, Germany, LOT: 400177) to form the PEEK core of the teeth

Acrylic resin denture base block fabrication :

A block of a diameter of 15 mm and length of 2 cm was designed by the computer-aided design/ computer-aided manufacturing (CAD/CAM) software (Sketchup Pro®)

Twenty-four Denture base block-shaped samples were 3D printed from Polymethyl methacrylate acrylic (PMMA) block (Ivoclar Vivadent, Schaan, Liechtenstein) eight blocks for each group **(Figure 1)**

The printed blocks were polished under running water with a 400-grit silicon carbide abrasive paper for 10 seconds

Surface roughness was done by diamond stone for the three types of teeth to rouge the bonding surface of the teeth to increase the surface area. The three types of teeth were bonded with the 3D printed PMMA block with pink wax (Modeling wax, Cavex, Holland)

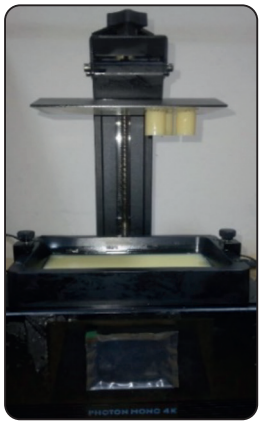

Fig (1) 3D printed PMMA block on the building platform

A dental stone mix (Durguix-Hard natural stone-Spain) was poured into the bottom part of the flask and The samples were coated with a separating medium and then embedded in the blending dental stone. **(Figure 2)**

Fig (2) Sample of the 3 Groups inserted in blending dental stone

Once the stone had hardened, a separating medium was applied to the hard stone to prevent it from sticking with the additional second stone mix. The other part of the flask was then securely closed and the flask vibrated to eliminate any trapped air bubbles.

The flask was placed in boiling water for 5 minutes so that the wax between the teeth and the PMMA block was softened

The upper and lower parts of the flask were separated and a mold was created by removing the printed PMMA block leaving each tooth in its position in the stone.

The softened wax was discarded from the flask so the mold and the surface of the teeth which bond with the acrylic resin were clean and free from any debris

A thin layer of methyl methacrylate monomer was applied to the roughened surfaces of the acrylic resin teeth to enhance chemical bonding. For Nanohybrid composite and PEEK teeth types, a bonding agent was applied to the bonding surface of the teeth to facilitate adhesive bonding with the acrylic resin denture base block sample.

The polymer and monomer components of the heat-cured acrylic resin (Acrostone Heat Cure Denture Base Material, Egypt) were blended according to the manufacturer's instructions.

The acrylic resin mixture was placed into the stone mold to bond with all types of teeth and subjected to a prolonged curing cycle (70°C for 9 hours). After the curing process, the flask was opened and all the samples underwent finishing and polishing.

PEEK teeth types were veneered with HICP (breCAM shade A3, bredent, Senden, Germany; Lot No. 406700)) to improve the aesthetics. **(Figure 3)**

Fig (3) three groups of samples after finishing and polishing and after veneered with HICP for group III

Wear Testing:

Before testing the wear of the teeth all samples were subjected to a thermo-cyclic protocol operated on a servo-motor (Model ACH-09075DC-T, AD-TECH Technology Co., LTD., Germany). The function of this device is to stimulate vertical and horizontal movements in a thermodynamic condition

The teeth of all samples were tested using a Dual-axis ROBOTA chewing simulator, which includes four chambers. Each chamber has an

upper compartment with a metal receptacle and a lower compartment. In the upper compartment, each sample was securely mounted into a metal receptacle, while a 600-grit sandpaper, serving as the antagonist material, was mounted in the lower compartment. **(Figure 4)**

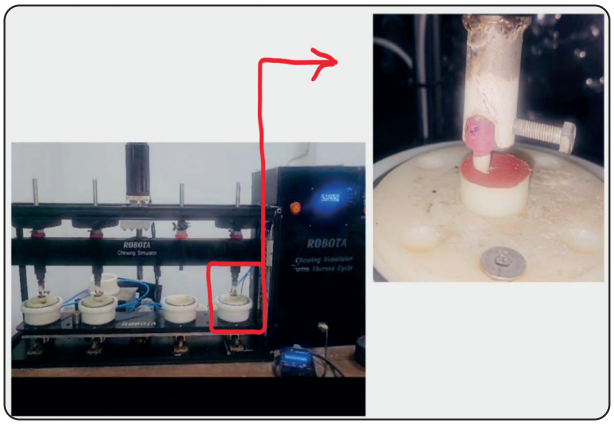

Fig (4) Dual-axis ROBOTA chewing simulator with sandpaper antagonist and sample mounted into a metal receptacle in the upper compartment during wear stimulation test

The sample was positioned so that the premolar's cusp was in contact with the sandpaper. A weight of 700 grams was applied and subjected to 10,000 cycles of rotation, lasting about 54 minutes.

Wear measurement :

The weight loss was done by weighing samples in the electronic analytical balance (Sartorius, Biopharmaceutical and Laboratories, Germany) and comparing the weight reading before and after wear stimulation. **(Figure 5)**

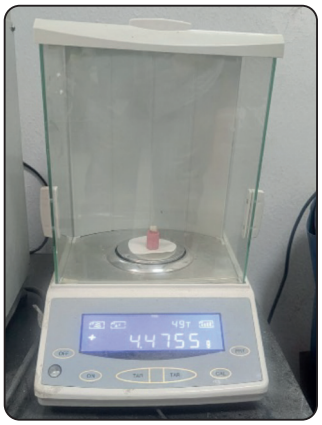

Fig (5) Sample mounted onto electronic digital balance during weighting

Microscopic evaluation:

The volume loss of the samples was achieved with the surface topographic feature by comparing the reading before and after wear stimulation **(Figure 6 A,B)**

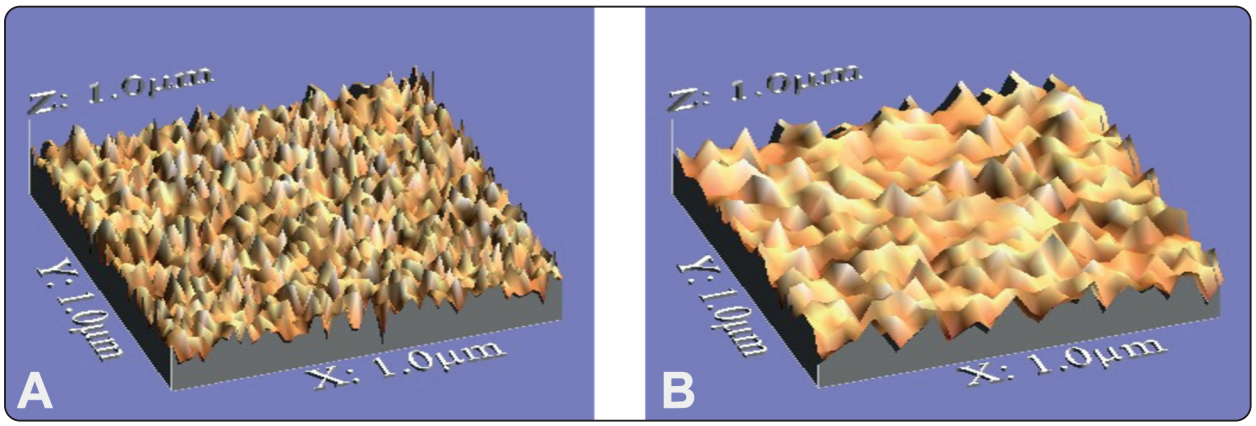

Fig. (6) A. PEEK sample volume recorded by surface topographic feature before wear stimulation B. PEEK sample after wear stimulation test

The wear on both the buccal and lingual cusps was photographed using a USB digital microscope with a built-in camera (Scope Capture Microscope, Guangdong, China) to enhance surface reflection of the teeth and allow for qualitative analysis of the wear areas. **(Figure 7 a -b-c)**

Shear bond strength Test :

Instron Universal Testing Machine (3345 model, England) was used to test the twenty-four samples **(Figure 8)** .

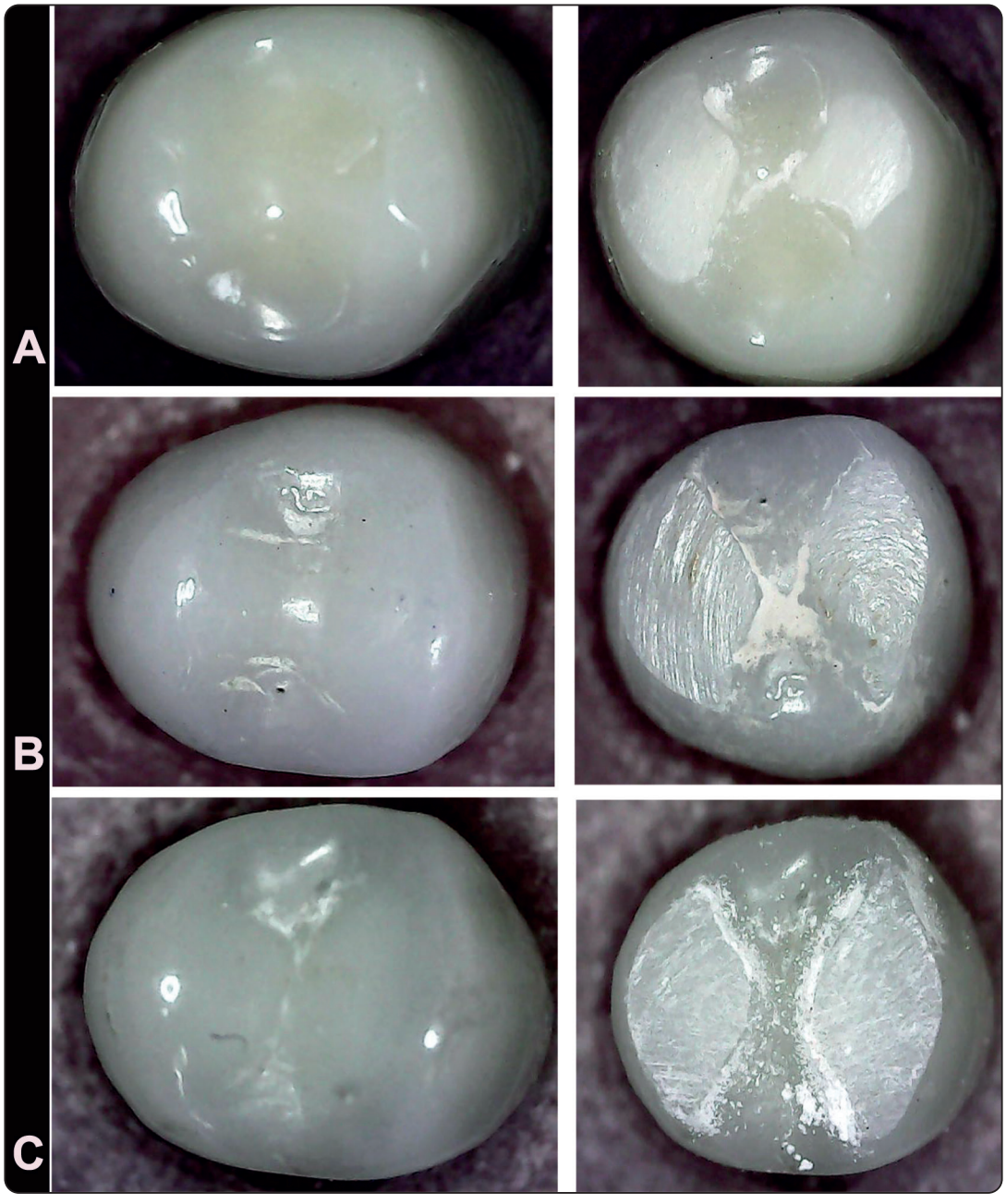

Fig. (7) A: Digital microscopic image for PEEK sample before and after wear stimulation -B.Digital microscopic image for Acrylic sample before and after wear stimulation-C. Digital microscopic image for NHC sample before and after wear stimulation

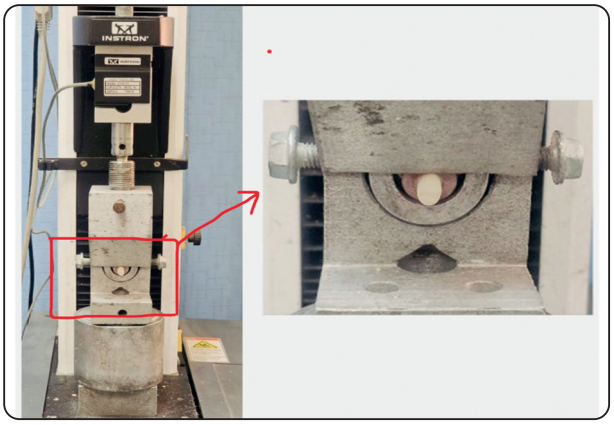

Fig. (8) Shear bond strength test set up with mounted sample onto the universal testing machine)

A shear force was applied until the samples debonded. The system's software recorded the failure point for each sample.

RESULTS

Statistical Analysis:

The study employed various statistical tests to analyze the data on weight loss, volume loss, and shear dislodgement of different denture teeth materials (PEEK, Acrylic, and NHC). The paired t-test was used to compare the means before and after the study for each material within the same group. A one-way Analysis of Variance (ANOVA) was utilized to compare the means among the three different groups. Furthermore, Tukey's post hoc test for multiple comparisons was applied to identify significant differences between specific groups after the ANOVA. The p-values from these tests were compared against the chosen significance level ($\alpha = 0.05$) to determine statistical significance

Weight loss :

The weight mean values and standard deviation for the wear test were measured by weight loss (grams) recorded for the three groups before and after the wear test stimulation

The weight mean value of the PEEK artificial tooth materials group was recorded (8.479) before wear stimulation and after wear stimulation was recorded (4.476) and the mean different weight loss was recorded (-4.003)as shown by paired t-test (P=0.0061)

The weight mean value of the Acrylic artificial tooth materials group was recorded (8.194) before wear stimulation and after wear stimulation was recorded (3.189) and the mean different weight loss was recorded (-5.005)as shown by paired t-test (P= <0.0001)

The weight mean value of the NHC artificial tooth materials group was recorded (9.169) before wear stimulation and after wear stimulation was recorded (3.163) and the mean different weight loss was recorded (-6.006)as shown by paired t-test (P=0.0001)

It was found that the NHC artificial tooth materials group recorded the highest mean difference weight loss (-6.006) followed by the Acrylic artificial tooth materials group which recorded (-5.005) and the lowest mean difference weight loss was found in the PEEK artificial teeth group and recorded (-4.003). the difference between the three groups was statistically significantly different as shown by One Way ANOVA (P<0.0001)

Volume loss

The volume mean values and standard deviation for the wear test were measured by volume loss (μm^3) recorded for the three groups before and after the wear test stimulation

The volume mean value of the PEEK artificial tooth materials group was recorded (30.71) before wear stimulation and after wear stimulation was recorded (21.71) and the mean different volume loss was recorded (-9.000)as shown by paired t-test (P=0.0072)

The volume mean value of the Acrylic artificial tooth materials group was recorded (33.81) before

wear stimulation and after wear stimulation was recorded (22.9) and the mean different volume loss was recorded (10.91)as shown by paired t-test (P= 0.0089)

The volume mean value of the NHC artificial tooth materials group was recorded (21.9) before wear stimulation and after wear stimulation was recorded (4.544) and the mean different volume loss was recorded (-17.36) as shown by paired t-test (P=0.0001)

The NHC artificial tooth materials group recorded the highest mean difference volume loss (-17.36) followed by the Acrylic artificial tooth materials group which recorded (-10.91) and the lowest mean difference volume loss was found in the PEEK artificial teeth group and recorded (-9.000). the difference between the three groups was statistically significantly different as shown by One Way ANOVA (P<0.0001)

Shear dislodgment

A shear load was applied with (N)until samples debonded. The system's software recorded the failure point for each sample.

The highest shear dislodgment force mean value was recorded (464.8) with bonded acrylic resin

TABLE (1) Paired t-test and One- Way Analysis of Variance of Amount of Weight Loss between Different Denture Teeth materials

	PEEK		Acrylic		NHC	
	Before	After	Before	After	Before	After
Mean	8.479	4.476	8.194	3.189	9.169	3.163
Std. Deviation	1.290	2.480	0.9170	1.009	0.1870	1.294
Std. Error of Mean	0.4876	0.9374	0.3466	0.3814	0.07068	0.4891
A lower 95% CI of the mean	7.286	2.182	7.346	3.256	7.996	2.966
Upper 95% CI of the mean	9.672	6.770	9.042	5.122	8.342	5.360
Mean Difference	-4.003 A		-5.005 B		-6.006 C	
P-value (Paired t-test)	0.0061 *		<0.0001 *		0.0001 *	
P-value (One Way ANOVA)			<0.0001 *			

Different letters in the same row indicated significant differences using multiple comparisons of Tukey`s post hoc test

****; Significant Different***

TABLE (2) Paired t-test and One -Way Analysis of Variance of Amount of Volume Loss between Different Denture Teeth materials :

	PEEK		Acrylic		NHC	
	Before	After	Before	After	Before	After
Mean	30.71	21.71	33.81	22.9	21.9	4.544
Std. Deviation	5.26	7.91	6.84	9.17	8.29	3.26
Std. Error of Mean	1.988	2.990	2.585	3.466	3.133	1.232
A lower 95% CI of the mean	25.85	14.39	27.48	14.42	14.23	1.529
The upper 95% CI of the mean	35.57	29.03	40.14	31.38	29.57	7.559
Mean Difference	-9.000 A		-10.91 A		-17.36 B	
P-value (Paired t-test)	0.0072 *		0.0089 *		0.0006 *	
P-value (One Way ANOVA)			<0.0001 *			

The same letters in the same row indicated insignificant differences using multiple comparisons Tukey`s post hoc test

Different letters in the same row indicated significant differences using multiple comparisons of Tukey`s post hoc test

****; Significant Different***

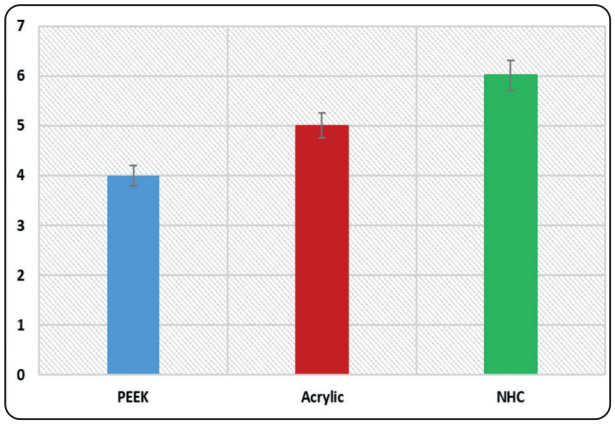

Fig (9) Column Plot of Amount of Weight Loss between Different Denture Teeth

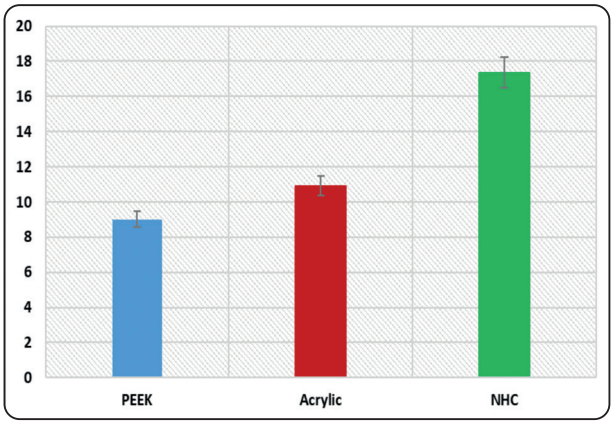

Fig (10) Nested Column Plot of the Amount of Volume Loss between Different Denture Teeth

denture teeth bonded to the conventional acrylic resin denture base block group followed by the bonded NHC to the conventional acrylic resin denture base block group which was recorded (337.2) while the lowest shear dislodgment force mean value was recorded (48.29) with bonded PEEK core veneered with HIPC teeth to the conventional acrylic resin denture base block, the difference between the three groups was statistically significantly different as shown by One Way ANOVA (P<0.0001)

Table (3): One-Way Analysis of Variance of Amount of Shear Dislodgemen force between Different artificial Denture Teeth materials :

	PEEK	Acrylic	NHC
Mean	112.2 A	464.8 B	337.2C
Std. Deviation	48.29	86.11	57.19
Std. Error of Mean	18.25	32.55	21.62
Lower 95% CI	67.53	385.2	284.3
Upper 95% CI	156.9	544.4	390.1
P-value (One Way ANOVA)		<0.0001 *	

Different letters in the same row indicated significant differences using multiple comparisons of Tukey`s post hoc test

****; Significant Different***

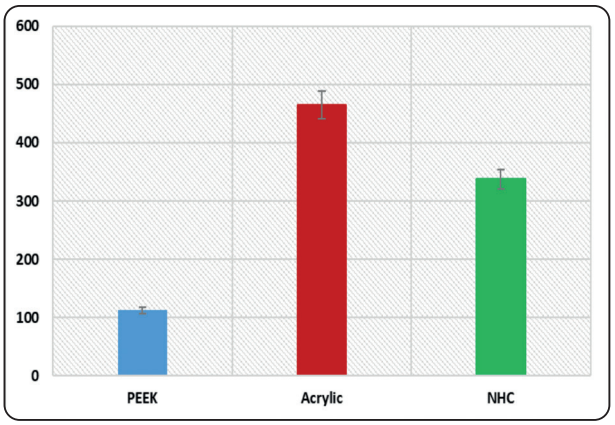

Fig (11) Column Plot of Amount of Shear Dislodgement force between Different Denture teeth materials

DISCUSSION

Wear resistance of denture teeth and the bond strength between the artificial teeth and the denture bases is an important topic in prosthodontic dentistry [24]. The debonding of denture teeth from the acrylic resin denture base affects the success of the treatment as it increases the number of patient appointments in the clinic and increases the cost of laboratory work as well as decreases the satisfaction of patients with their complete or partial denture [25,26], while the wear of the occlusal surface of artificial teeth affects the function of the removable dentures by decreasing tooth support and the loss

of chewing efficiency [27,28] Many new materials are used to improve wear resistance and bond strength of the denture artificial teeth [29]

The wear stimulation test in this study found that there is a statistically significant difference between the three groups where it was found that (PEEK) core veneered with (HIPC) teeth show the highest wear resistance followed by Nanohybrid composite teeth (NHC) while the lowest wear resistance was found in acrylic resin teeth after measuring the weight loss and volume loss before and after wear stimulation test.

The highest wear resistance of the PEEK core veneered with HIPC tooth could be due to one of the most important properties of PEEK which is the High elasticity that leads to stress distribution during function and thus reduces stress and torque on the tooth as well as its high mechanical strengths and stability which provide rigidity to the PEEK theses properties make the core strong and withstand masticatory forces and decreases wear of the tooth providing high wear resistance [30,31] as well as the HIPC shows higher flexural strength which makes this type of composite withstand the chewing forces. [32]

One of the studies agrees with this study's results as when the authors compare the wear resistance between different tooth materials they found that PEEK shows high wear resistance when compared to nanohybrid composite and polymethyl methacrylate and the authors explained these results by the low abrasiveness to enamel of the PEEK and its high wear resistance [33]

Nanohybrid composite shows the lowest wear resistance when compared to both acrylic resin and PEEK tooth and this is due to that NHC composition contains inorganic silanized sio2 although these fillers increase the hardness of the composite but it detaches from the denture teeth surface during function and causes excessive wear [34]

One of the studies agrees with this study's result as the authors compare the wear resistance between nanohybrid composite and acrylic teeth it was found that acrylic teeth show higher wear resistance than the nanohybrid composite due to the composition of the acrylic resin teeth which is free from any filler and this give the acrylic resin denture teeth more homogenous structure and improve wear resistance[35]

Measurement of shear dislodgment found that there is a statistically significant difference between the three groups where the highest bond strength was found in Group I: (Acrylic resin teeth bonded to conventional acrylic resin denture base block) followed by Group II (Nanohybrid composite teeth (NHC) bonded to conventional acrylic resin denture base block) while the weakest bond strength was found in Group III(Polyether Ether Ketone(PEEK) core veneered with High-Impact Polymer Composite(HIPC) teeth bonded to conventional acrylic resin denture base block)

The highest shear bond strength was found in bonded acrylic resin teeth to conventional acrylic resin denture base block this result was reported because the acrylic resin tooth and acrylic resin denture base have the same composition which makes them bond with each other chemically by polymerization process this bond mechanism provides a strong attachment when compared with the other two types of tooth materials which bonded with acrylic resin denture base mechanically by surface roughness and surface treatment [36,37]

One of the studies agrees with this study result where the authors compare the bond strength of the acrylic tooth and the composite tooth to the acrylic resin denture base and they report that the bond strength of the acrylic tooth with the acrylic resin denture base shows higher bond strength than that of the composite tooth with the acrylic resin denture These results can be explained by the absorption of monomer through the surface layers of teeth due to

the chemical bonding between acrylic teeth and the polymer monomer dough occurs.[38]

The lowest shear bond strength found in (PEEK) core veneered with High-Impact Polymer Composite (HIPC) when compared to the other tooth materials groups is that the PEEK has a very inert surface that leads to poor bonding to dental materials and needs excessive surface treatment than nanohybrid composite [39,40]

CONCLUSION

Group I: Acrylic resin teeth bonded to conventional acrylic resin denture base block group) shows the highest bond strength with acrylic resin denture base and moderate wear resistance

Group II: Nanohybrid composite teeth (NHC) bonded to conventional acrylic resin denture base block shows moderate bond strength with acrylic resin and lowest wear resistance

Group III: (PEEK) core veneered with (HIPC) teeth bonded to conventional acrylic resin denture base block group shows the highest wear resistance and the lowest bond strength.

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