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The Effect of Preheating and Flowable Composite on the Marginal Integrity of Class II Composite Resin Restorations

Yasmin .A. Elkady, Ali .I Abdalla,Mostafa. M. Hasan.
Ali .I Abdalla, Professor of Restorative Dentistry, Faculty of Dentistry, Tanta University,Egypt
Mostafa.M. Hasan, Professor of Restorative Dentistry, Faculty of Dentistry, Tanta University, Egypt
Corresponding Author: Yasmin .A. Elkady
BDS, Restorative Dentistry, Faculty of Dentistry, Tanta University, Egypt

Abstract
Objective: *To evaluate the effect of preheating and flowable composite on the marginal integrity of Class II composite resinrestorations.*
Materials and Methods: *Forty extracted human sound molars were used in this study. Class II cavities were prepared. The cavities were prepared using carbide bur with water spray and finished with fine- grained diamond stone. The cervical margin was established 1.5 mm above the cement - enamel junction. The overall dimensions and depth of the cavity were standardized as follow: 4 mm length occlusocervically and 4 mm width buccolingually and 2 mm depth axially. The cavity depth and length were judged with a permanent mark on the bur and then verified using a periodontal probe.*
The teeth were randomly divided into four groups (n=10 each): Group 1: Cavities were restored with (Grandio) composite, Group 2: Cavities were restored with preheated (Grandio) composite, Group3: Cavities were restored with (Grandio Flow) flowable composite followed by (Grandio) composite, Group4: Cavities were restored with (Grandio Flow) flowable composite followed by preheated (Grandio) composite.
Futurabond DC (one-step self-etch adhesive) was used in all groups. The specimens in each group were thermocycled in a thermo-cycling apparatus for 600 thermal cycles. Impressions of the teeth were made and then poured with epoxy resin and replicas were examined under SEM to examine margin gaps.
Result: *The highest percent of open margin was recorded for group 1, recording 26.66% followed by group 3, recording 24.16%, while the lowest mean marginal gap length value 13.33% was found at group 4.There were no significant difference between group 2 and group 4.*
Conclusion: *Application of flowable composite as a liner in composite restorations cannot reduce microleakage but preheating the resin composite to elevated temperature, i.e. 60°C, increases the adaptation and lowers the gap at restoration margin.*
Keywords: *Resin composite;* ***Preheating****; marginal gap.*

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I. Introduction

In the last decade, growing demands by patients for esthetic restorations have markedly increased the use of direct, light-activated resin composites in restorative dentistry.[1]

The durability of these restorations depends on their marginal integrity which is defined as the degree of proximity of a restoration to a tooth surface. The marginal gap can start forming from a space created between the restoration and tooth, 0.5 to 1 um wide, where bacteria, oral fluids and debris may enter and destroy the bond decreasing the longevity of the restoration and speeding up its functional and mechanical failure.[2]

These gaps could be formed due to the contraction or shrinkage ofcomposite based resins during conversion from monomer to polymer. The resin matrix shrinks volumetrically approximately 10 percent during polymerization. This polymerization shrinkage stresses the adhesive between the tooth and the restorative material, frequently resulting in failure of this bond and marginal infiltration.[3]

This has activated producers to find solutions and to modify either the material or the technique or both to improve adaptation of the composite by lowering its viscosity. The effect of lowering viscosity has been shown to be important.[4] Compared with conventional composite resins, these new composite resins with low viscosity was found to be more easily applicable to cavities with complicated forms and require shorter time for the restorative procedure beside their excellent sealability.[5]

One of the methods used for decreasing composite viscosity is the development of flowable resin composites. These achieve their lower viscosity primarily by a reduction in reinforcing filler content and changes in the matrix chemistry .They can improve the wettability by flowing onto all prepared surfaces creating an intimate union with the micro structural defects in the floor and the walls of the cavity preparation.[6]

Moreover, they act as a flexible intermediate layer that helps to relieve stresses during polymerization shrinkage of the restorative resin. These characteristics and a syringe delivery system make them an ideal choice for the use as a liner .[7]

The application of flowable resins was expanded to posterior restorations. However, posterior restorations are considerably stressed by cyclic loading during mastication. Consequently, resin composite restorations are subjected to occlusal wear over time due to its low filler content. [8]

So it is well known that a decrease in filler content will affect various properties of a hardened composite resin, such as the mechanical strength and curing shrinkage .[9]

Against this background, it is important to investigate how to lower the viscosity of a composite resin without decreasing its filler content. [10] so the most uncomplicated method of decreasing the viscosity of composites is to lower the viscosity of the monomer mixture itself .[10]

Many polymer resins exhibit lower viscosity when they are heated. The theoretical basis for this behavior is that thermal energy forces the composite monomers or oligomers further apart, allowing them to slide by each other more readily. Studies have shown that heating general polymers and resin composites lowers viscosity and thereby improves adaptation .[11]

An additional advantage of heating the resin composite prior to placement and polymerizing is the accompanying increase in monomer conversion.[12]With increased paste temperature, free radicals and propagating polymer chains become more mobile as a result of decreased paste viscosity and react to a greater extent, resulting in a more complete polymerization reaction and greater cross-linking. The increase in polymerization may lead to improved mechanical properties and increased wear resistance.[12-13]

There are several methods that can be used to preheat the composite. One of them is adevice that lowers the viscosity of regular dental composites called (Calset)[*]. This device can heat material to 37℃, 54℃ or 68℃ and also maintain constant temperature.[14]

Instead of this devise, light of dental unit chair might be used to raise the temperature of composite resin. Consequently, micro hardness and degree of conversion also will increase.[14]A another method used to preheat composite resin is wrapping it by hand for 3 - 5 minutes, so temperature of resin will be raised slightly.[14]

It was found that preheating micro hybrid or packable resins improve their flowability and that may result in more accurate adaptation to the peripheries and the retentive features of the cavity. This also allows placing and curing each increment of composite at its ideal polymerization temperature. [15]

II. Materials and methods

Study design: The study was conducted as a randomized controlled laboratory trial**.**

Study setting: The study was carried out at Restorative Dentistry Department, Faculty of Dentistry, Tanta University.

Sample size: Forty extracted human sound molars were used in this study. These teeth were collected from Oral Surgery Department at Tanta University. The teeth were extracted due to periodontal diseases form diabetic patients aged (25-40) years old. The teeth were cleaned from tissue remnants and debris using periodontal scalers and curettes and were polished with pumice then immersed in 10% formalin for 5 days for disinfection and then stored in 0.1% thymol solution.

Ethical considerations: Approval for this project was obtained from Faculty of Dentistry, Tanta University Research Ethics Committee. The purpose of the present study was explained to the patients and informed consents were taken from them to use their teeth for research, according to the guidelines on human research published by the Research Ethics Committee at Faculty of Dentistry, Tanta University. **(Appendix)**

a) Materials:

- The materials that were used in this study (as shown in table1) were two types of Nano-hybrid composites (Grandio), a flowable composite(Grandio Flow)andself-etch adhesive (Futurabond Dual Cure).
- The chemical composition, manufacturer, web sites and batch numbers of each material are shown in Table 1.
- C-Warmer: It has freely adjustable temperature between 20^0 C~60^0 C with digital display and has one large slot which can fit compule dispenser gun or composite resin syringe. Also one medium slot which can fit larger sized cartridges(Figure1).

b) Methods:

- **Preparation of specimens:** Each tooth was fixed with sticky wax to the base of plastic cylinder. The cylinder was filled with self-curing acrylic resin so that only roots were embedded within the self-curing acrylic

[*] Calset composite warmer (AdDent, Inc., Dandury, CT, USA)

resin (Figure**2**)Box class II cavities with parallel walls were prepared using carbide bur[1] (Figure **3**) with water spray. Each bur was replaced after 5 preparations .[16]
The cavities were finished with fine- grained stone. The cervical margin was established 1.5 mm above the cement - enamel junction. The overall dimensions and depth of the cavities were standardized as follow: 4 mm length occlusocervically and 4 mm width buccolingually and 2 mm depth axially. The cavity depth and length were judged with a permanent mark on a periodontal probe (**4, 5, and 6**).

Grouping of specimens:
All specimens were randomly divided into four groups (n=10 each) according to the procedure of restoration following manufacturer's instructions as follow: (Figure**7**)
Group 1: Cavities were restored with (Grandio) composite.
Group 2: Cavities were restored with preheated (Grandio) composite
Group3: Cavities were restored with (Grandio Flow) flowable composite followed by (Grandio) composite**Group4:** Cavities were restored with (Grandio Flow) flowable composite followed by preheated (Grandio) composite.
Futurabond DC Universal adhesive (one-step self-etch adhesive) was applied in all groups using a disposable micro-brush, rubbed for 20 seconds, dried with gentle steam of air for 5seconds and light cured usingBlue phase N [2] for 10seconds according to manufacturer's instructions.
The compule was inserted into the composite gun. Metallic matrix retainer and band[3] were used to restore the missing wall of the tooth. Incremental application of Grandio composite resin was performed each of 2mm thickness then light cured using Blue phase N .(Figure **8**)
Group1: Grandio composite resin was applied incrementally and each increment was in 2 mm thickness then light-cured for 20s using Blue phase N curing device according to manufacturer's instructions.
Group2: The compule was placed directly into the delivery syringe to be preheated. Grandio composite was pre-heated to 60°Cin the C-Warmer deviceand then inserted into the cavities.The compule was then returned to the C-Warmer device after application of the first increment to avoid temperature loss during curing of the first increment.[17] The composite was cured immediately for 20 secondsusing Blue phase N.
Group3: The flowable composite (Grandio Flow) was placed in a 1 mm thick layer to line the axial wall of cavity and cured for 20 seconds, over thatGrandio composite was inserted as done previously in group 1.
Group4: The flowable composite (Grandio Flow) was placed in a 1 mm thick layer to line the axial wall of cavity and cured for 20 s, over that Grandio composite was inserted as done previously in group 2.[125]
In all groupsafter composite curing, restorations were contoured by #D8 diamond stone and finished by finishingdiamond stone and then polished with flexible disks[*] and polishing past .After that all specimens were kept in water for 24 hours .
Thermocycling:
The specimens of each group were thermocycledin a thermo-cycling apparatus [4]by alternating immersion in water bath at 5^0c and 50^0c with a dwell time of 2min for 600 thermal cycles which corresponds to 12 months of clinical service.[18]

Evaluation of Marginal Adaptation:
Impressions of the specimens were made using a Polyvinyl Siloxane material (light body). The impressions were then poured with epoxy resin[5]. These replicas were left 24 h for complete setting. Then, Gold sputtered to render the surface electrically conductive.

These replicas were examined under Scanning Electric Microscope (SEM)[6] at 30 Kv power with different magnifications (50x, 500x) to study restoration-tooth interface. The low magnifications (50x) provided an overview of the proximal surface of each sample at the level of the interface, whereas with high magnification (500x) viewed the interface at the selected area of the restoration.

The resultant SEM micrographs were scanned on A monitor screen, then they were transferred onto Orion 6.60.4 software program and these images were ready on a computer screen to determine marginal fit and measure any formed gaps.

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[1] OKO dent, H 21 012FG (Germany)
[2]Ivoclarvivadent
[3] Universal Tofflemire's matrix retainer and band
* 3M Espe USA
[4]Custom made apparatus at Conservative dentistry department, Faculty of Dentistry, Alexandria University.
[5]Chemical Industries for construction, CIC, Egypt
[6]JSM-5300 scanning microscope, JEOL, Peabody, MA, USA.

III. Results

Gap length and width:

1- Length of marginal gap*:*

SEM photographs of the tested specimen were used for gap length measurement using AutoCAD software. This was determined as the ratio of the length of gaps to the total length of the margins, and then converted to a percentage. So, the length of marginal gap formed was calculated as a percentage of the entire margin length. The recorded data related to each group were collected, tabulated and statistically analyzed.

It was found that, the highest mean value of gap length was recorded for group1, recording 3.24 mm ±0.36 (26.66%) followed by group 3, recording 2.9 mm ±0.23(24.16%), while the lowest mean marginal gap length value 1.68 mm ±0.13 (13.35%)was found at group 4. There were no significant difference between group 2 and group 4.

One –way ANOVA test was used to compare the tested groups at a level of significance $P<0.001$ and reported a high statistical significant difference.

Tukey`s test was performed to find out which group is responsible for the recorded difference as shown in Table (2)

2-Gap width:

The composite/tooth interface was divided into three regions and measurements of marginal gap widths in each region were made at 500× magnification. The largest marginal gap width in each region was recorded in micrometers (μm), and the mean gap widths for tested groups were calculated.

SEM photographs of the tested specimens with higher magnification(x500) were used for gap width measurement using mean of raw data. The recorded data related to each group were collected, tabulated and statistically analyzed.

a- Width of proximal gap:

The mean values of marginal gap width (µm) ±SD of the data collected from all tested groups (1, 2, 3 and 4) were tabulated.

It was found that, the highest mean value of gap width proximally was recorded for group 1, recording 184.25 µm ±6.79followed by group 3, recording 177.05 µm ±10.25, while the lowest mean marginal gap length value 30.75 µm ±15.28was found in group 4.There were no significant difference between group 2 and group 4.

ANOVA one -way test was used to compare the tested groups at a level of significance $P<0.001$ and reported a high statistical significant difference as shown in

Tukey`s test was performed to find out which group is responsible for the recorded difference shown in Table (3).

b- Width of cervical gap:

The mean values of marginal gap width (µm) ±SD of the data collected from all tested groups (1, 2, 3 and 4) were tabulated.

It was found that, the highest mean value of gap width cervically was recorded for group 1, recording 225.9 µm ±24.92 followed by group2, recording 268.2 µm ±16.45, while the lowest mean marginal gap length value 79.10 µm ±8.26 was found at group 4.There were no significant difference between group 2 and group 4.

ANOVA one -way test was used to compare the tested groups at a level of significance $P<0.001$ and reported a high statistical significant difference.

Tukey`s test was performed to find out which group is responsible for the recorded difference as shown in Table (4).

IV. Discussion

In the current study it was found that, the highest percent of open margin was recorded for group1 restored with Grandio, recording 26.66% followed by group3(restored with Grandio &Grandio Flow), recording 24.16%.There were no significant difference between using the composite alone and using flowable composite under it.

This result was explained and agreed with **Boruziniatet al.,**[19] who have evaluated existing evidence to verify whether an application of flowable composite as a liner provided less microleakage in Class II composite restorations and their conclusion was that the application of flowable composite as a liner in composite restorations cannot reduce microleakage or improve clinical performance.

Similar result was obtained by **Güngör et al.,**[20] who compared the occlusal and gingival microleakage of Class-II composite restorations utilizing etch-and-rinse and self-etch adhesives and different liner materials in primary and permanent teeth .They found that occlusal microleakage was similar in both primary and permanent teeth, while a lesser extent of gingival seal was observed in primary teeth. Overall, placement of a liner material did not improve resistance to microleakage.

On the other hand**,Niketet al.,**[21]disagreed with our results. In their study they concluded that the use of flowable composite as a liner under hybrid and packable composites had shown a trend toward less leakage compared to hybrid and packable composites alone.

They explained their result that Resin-rich flowable composites, which has low viscosity, adapt as well as hybrid composites to cavity margins. Their low modulus of elasticity allows for plastic deformation, which acts as an elastic buffer and increase the flexibility of the bonded assembly and might act as a shock absorber and thus compensates for contraction shrinkage stress when used as a liner.

In the present study there were no significant difference between group2 restored with preheated Grandio (15.70%) and group 4restored with Grandio Flow& preheated Grandio(13.33%) showing the lowest marginal gap length found at group 4 .

This was in the same line as Choudhary**et al.,**[22] who evaluated and compared total gap surface area formed after retorting Class II cavities with Filtek Z350 and P60 at room temperature, 37°C and 54°C.They found that there was an average reduction in total gap surface area, from room temperature to 54°C, in both Filtek Z350 and P60 groups.

They explained their results that the decrease in system viscosity and enhanced radical mobility at increased temperatures, resulting in additional polymerization and higher conversion. The collision frequency of unreacted active groups and radicals increases with elevated curing temperature when below glass transition temperature. Also, at elevated temperatures, there is free volume increase, giving the trapped radicals increased mobility, resulting in further conversion.

This also came in agreement **with Elsayad,**[23] who aimed to determine the effect of preheating resin composite to three different temperatures on the cuspal movement and gap formation at the tooth/restoration interface

The author found restoring a layer of Tetric Flow followed by Tetric Ceram HB showed the highest gap total surface area and linear pulpal gap, which may be attributed to the high polymerization shrinkage of flowable composite which was attributed to its low filler content.

Currently the occlusal gaps were less than the cervical gaps. Similar results have been observed in previous microleakage studies by **Wagner et al.,** [24] .These findings indicate that better sealed interfaces are formed at the occlusal margins than at the cervical margins.

This could result from stronger bonding of the unset and set composite to enamel and the geometry of the restoration .The most accepted theory is that the greater amount of enamel at the occlusal margins allows for better sealing and reduced microleakage. However, the geometry of the restoration could have also been important as the longer vertical dimension would result in more composite shrinkage in that direction. This, in turn, would then put more strain on the cervical margins.

So the null hypothesis of the current study is accepted

Adding that at elevated temperatures, a more rapid photopolymerization occurs. These high reaction rates may lead to higher stress formation and faster development of the gel point, providing detrimental effects to the integrity of the resin/tooth interfacial bond. This might be an explanation for the significant increase in total gap surface area and linear pulpal gap of restorations preheated to 68°C compared to these preheated to 37°C and 54°C.

Furthermore, it was expected that curing composite at a very high temperature, such as 68°C, would increase the amount of thermal contraction during cooling. Resin composite preheated to 37°C recording the least gap total surface area.

On the other hand**,Sabatini et al.,**[145] disagreed with the current results. They evaluated the effect of preheated composites and flowable liners on the gingival margin gap formation of Class II composite restorations versus those placed at room temperature . They found that preheated composites did not significantly reduced gap formation at the gingival margin.

They mentioned that preheating composites may yield benefits in other ways. By achieving a transient viscosity reduction comparable to that of flowable resins, an enhanced adaptation of the resin to all intricacies of the preparation may be obtained. At the same time, no restorative compromise was made, since a hybrid resin with high strength and high filler loading was used as the initial gingival increment.

They explained their result that the use of low viscosity materials was highly technique-sensitive as low viscosity materials were difficult to manipulate easily and entrapping air during removal of the syringe. Also they mentioned that Flowable resins and preheated composites must be carefully applied to the preparation in only one direction, and removal must be done by gently wiping the compule tip against the preparation walls. Finally they had a speculation that the operator's technique may have had an influence on the observed results.

V. Conclusion

Under the conditions of present study, the following conclusions can be made.

1-The application of flowable composite as a liner in composite restorations didn't reduce microleakage .

2- Preheating the resin composite to elevated temperature, i.e. 60°C, is a useful technique since it increases the adaptation and lowers the total gap surface area.

VI. Recommendations

Based on the findings of this in-vitro study, the following recommendations could be drawn:

1. In-vivo studies are required to evaluate the clinical performance of preheated composite.
2. Also, more in-vitro studies are required to test the mechanical and physical properties of preheated composite.
3. Further studies with a larger sample size, involving various restorative materials, need to be undertaken in order to assess the best temperature of preheating for optimum clinical advantage.
4. Also studies are required to evaluate the effect of preheating on the dentine-pulpal organ.

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Figure (1): C-Warmer : Anesthetic / Composite Warmer .

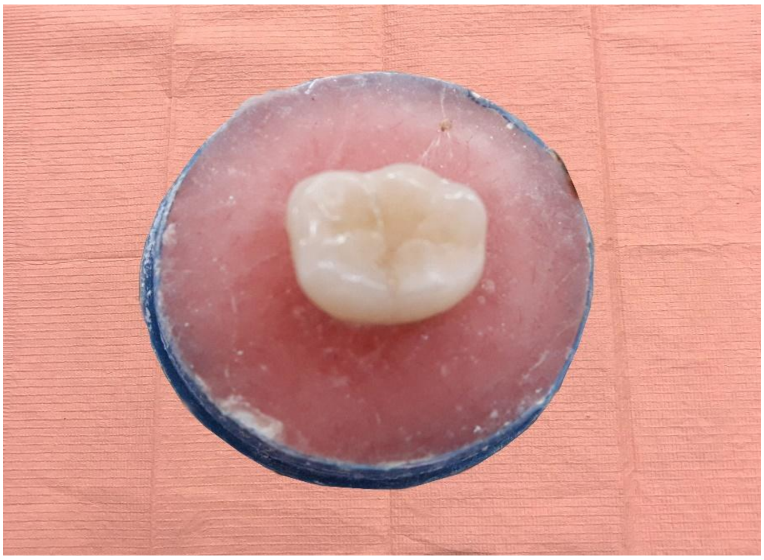

Figure (2): Tooth mounted in a plastic cylinder using with self-curing acrylic resin

Figure (3): Carbide Bur

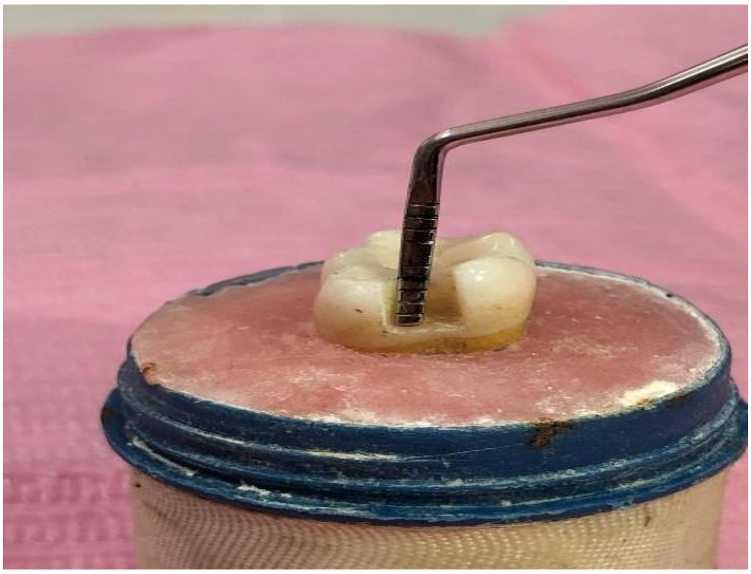

Figure (4): The cavity length (4mm) was verified using a periodontal probe

Figure (5): The cavity width (4mm) was verified using a periodontal probe

Figure (6): The cavity depth (2mm) was verified using a periodontal probe

Figure (7): Futurabond DC-Grandio-Grandio Flow

Figure (8): Universal Tofflemire's matrix retainer and bandused to restore the missing wall of cavity

Table 1: Chemical composition, manufacturer and web site of tested materials in this study are shown in Table (1).

Materials	Chemical Compositions	Manufacturer	Website
Grandio	87 % w/w inorganic fillers (71.4 Vol. %) in a methacrylat matrix (Bis-GMA, TEGDMA) and cures under halogen or LED lights (blue light).	VOCO Gmbh, CUXhaven, Germany	www.voco.de
Grandio Flow	80% w/w inorganic fillers (= 65.6 %vol.) in amethacrylate matrix (Bis-GMA, TEGDMA, HEDMA) and cures under blue light (halogen/LED)	VOCO Gmbh, CUXhaven, Germany	www.voco.de
Futurabond DC	organic acids, Bis-GMA, HEMA, TMPTMA, campherchinon, amines (DABE), BHT, catalysts, fluorides and ethanol	VOCO Gmbh, CUXhaven, Germany	www.voco.de

Table (2): Tukey`s test between tested groups at a level of significance (P<0.001)

Comparison	Absolute Difference	Critical Range	Results
Group 1 to Group 2	1.2227	0.323724136	Means significantly different
Group 1 to Group 3	0.2122	0.323724136	Not significantly different
Group 1 to Group 4	1.43895	0.323724136	Means significantly different
Group 2 to Group 3	1.0105	0.323724136	Means significantly different
Group 2 to Group 4	0.21625	0.323724136	Not significantly different
Group 3 to Group 4	1.22675	0.323724136	Means significantly different

Table (3): Tukey`s test between tested groups at a level of significance (P<0.001)

Comparison	Absolute Difference	Critical Range	Results
Group 1 to Group 2	131.15	12.67761492	Means significantly different
Group 1 to Group 3	7.2	12.67761492	Not significantly different
Group 1 to Group 4	153.5	12.67761492	Means significantly different
Group 2 to Group 3	123.95	12.67761492	Means significantly different
Group 2 to Group 4	12.35	12.67761492	Not significantly different
Group 3 to Group 4	146.3	12.67761492	Means significantly different

Table 4: Tukey`s test between tested groups at a level of significance (P<0.001).

Comparison	Absolute Difference	Critical Range	Results
Group 1 to Group 2	168.575	19.42392751	Means significantly different
Group 1 to Group 3	12.3	19.42392751	Not significantly different
Group 1 to Group 4	176.8	19.42392751	Means significantly different
Group 2 to Group 3	180.875	19.42392751	Means significantly different
Group 2 to Group 4	8.225	19.42392751	Not significantly different
Group 3 to Group 4	189.1	19.42392751	Means significantly different

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