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Efficacy of Bulk Fill Flowable Composite Reinforced with Short Fibers in Fracture Resistance of Restored Extensive Premolars Cavities

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ABSTRACT

Objectives: Tooth fractures are a frequent side effect after MOD restorations. This investigation aimed to evaluate the impact of bulk fill flowable composite reinforced with short fibers concerning maxillary premolar teeth's resistance to fracture, All teeth used have extensively restored MOD cavities. **Materials and Methods:** In this in vitro experimental study, Selecting sixty maxillary sound premolar teeth, they were kept in a chloramine solution. After that, the teeth were set into acrylic blocks. 1mm below the CEJ.The teeth were grouped into four groups of fifteen each at random. Group A, Teeth were intact without any cavity (negative control). Wide MOD cavities were done by cylindrical bur for the 3 other groups. Group B, the teeth with MOD cavities without any restoration (positive control); Group C, the teeth were filled with bulkfill flowable composite Tetric N flow bulk fill (Ivoclar Vivadent); and group D, the teeth were restored with short fibers reinforced bulkfill flowable composite ever X Flow(GC). After storage for 24-hour period in water at 37°C, the teeth's ability to withstand fractures was evaluated by (INSTRON). The load was measured in N at the fracture. Mode of fracture was observed. One-way ANOVA was utilized to analyze the data. **Results:** The mean fracture strength was 1216 ± 352 N in group A, 330 ± 201 N in group B, 1013 ± 389 N in group C and 1019 ± 164 N in group D. **Conclusion:** The restoration of extensive MOD cavities using flowable composite with short fiber reinforcement enhanced the teeth's resistance to fracture from compressive forces, with no difference than did the other bulk fill flowable composite.

KEYWORDS

MOD restorations, Bulk fill Flowable composite, Short fibers, Dentine, Fracture resistance.

INTRODUCTION

Fracture resistance is reduced when tooth structure, particularly marginal ridges, is removed during cavity preparation. The weaker teeth can be strengthened by adhesive materials, which can lead to a partial or complete recovery of fracture resistance. This has led to their regular use in everyday practice in addition to the composite restorations have adequate aesthetics and mechanical performance.[(1)]

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Numerous difficulties arise with large direct restorations, particularly in the posterior dentition. It takes specific skills to master the shape, contours, occlusal anatomy, and function. It is important to understand the possible risk factors and typical failure patterns in the posterior region. Bulk fracture and secondary caries are the two main causes of posterior restoration failure that have been identified. While caries was more likely to be the cause of long-term failure, early failure was more closely associated with fractures. Long-term studies (more than a decade of follow-up) found that fractures rather than caries were more often the cause of this failure. This result implies that, irrespective of the lifespan or age of these restorations, bulk fracture poses a significant risk to posterior restorations. (2)

Several studies have explained layering protocols by demonstrating that, in comparison to bulk filling, layering may actually exacerbate shrinkage stresses rather than lessen them. Therefore, Manufacturers have focused more on simplification in recent years, employing novel materials for bulk filling, with encouraging outcomes (strength & stress reduction) in both flowable and packable form. (3)

The application of fiber-reinforced composite (FRC) technology has a well-documented history in industry, but it is always changing due to creative treatment methods that boost fracture resistance. In order to create devices with high strength and fracture resistance, engineering and architectural applications have long used a variety of fiber types with different orientations and lengths. Since the early 1960s, the use of FRC in dental applications has been covered in the literature. In restorative dentistry, fiber reinforcement is now a preferred and effective material. (4,5)

The goal of introducing short fiber-reinforced composite (SFRC) to the market in 2013 was to imitate dentine's ability to absorb stress. The SFRC material is designed to be used as a bulk base for the restoration of both vital and non-vital teeth in high stress areas. (6) Within the bulk-fill material family, it has a higher flexural modulus and fracture resistance, but it is still easily applied in 4-mm deep increments and may even be able to match dentin's fracture resistance. (7, 8)

It is made up of inorganic particulate fillers, randomly orientated E-glass fibers, and a resin matrix. The semi-interpenetrating polymer network (semi-IPN) in the resin matrix increases the polymer matrix's fracture resistance and enhances bonding qualities for repairs.(9)

The use of fiber reinforcement is justified in part by its ability to prevent fractures and in part by its ability to strengthen the tooth from the inside out. The types of resins used, the length, orientation, and position of the fibers, as well as their adhesion to the polymer matrix and impregnation into the resin, all affect how effective fiber reinforcement it. (4)

Stress transfer from the polymer matrix to the fibers underlies the reinforcing effect of the fiber fillers. Still, each fiber serves as a crack stopper on its own. It is crucial for stress to be transferred from the polymer matrix to the fibers. Only when the fibers are at least as long as the critical fiber length is this feasible. E-glass microfibers have critical fiber lengths to diameter ratios ranging from [140 μm in length and 6 μm in diameter]. Furthermore, it is well known that a structure's mechanical characteristics are influenced by the placement and orientation of its reinforcement. (10)

When applied in accordance with biomimetic principles, the question of whether this new flowable SFRC material can reinforce the dental structure that leads to improved fracture resistance and more favorable fracture patterns arises. (11) Therefore, the only goal of the current study was to provide clinicians with a comparative overview regarding the flowable SFRC made of biomimetic material and bulk fill flow posterior restorative material's resistance to fracture.

MATERIALS AND METHODS

Teeth selection:

After the local ethics committee approved the study protocol, 60 intact maxillary premolars that needed to be extracted for orthodontic purposes were chosen. The buccolingual (BL) and mesiodistal (MD) dimensions of the teeth were chosen to be roughly comparable (9.2 ± 0.5 and 7 ± 0.5 mm, respectively). Teeth with fracture lines and flaws were not included. Following cleaning, the teeth were placed in distilled water and then 0.5% chloramine solution for storage.

All of the teeth's roots were embedded up to 1 mm apical to the cemento-enamel junction (CEJ) in a cylinder of self-curing acrylic resin after being thinly coated (0.2–0.3 mm) with wax. The teeth were taken out of the resin cylinder once the resin had set, and the covering wax was melted by submerging it in boiling water.After placing impression material made of polyether in this gap, the teeth were put back into the cylinders. The layer that was left over resembled the periodontal ligament. The tooth's long axis was perpendicular to the cylinder's base.

Cavities preparation:

Using cylindrical diamond burs, 45 randomly chosen premolars were prepared for standardized wide mesio-occluso-distal (MOD) cavities, with the gingival margin positioned 1 mm coronal to the CEJ. The measurements of the cavity were as follows: proximal box width = 1/2 of buccolingual dimensions; occlusal width = 1/2 of inter-cuspal width; pulpal depth = 2.5 mm; and axial depth = 1.5 mm. The cavity walls on the face and palatal regions ran parallel to the teeth's long axis. Internal line angles were rounded, and the cavosurface margins were prepared at a 90° angle.

All the arrangements were made by one skilled operator. To ensure correct and precise standardization of cavity dimensions, measurements were taken using a caliper with a sensitivity of 0.2 mm.

Table (1) *The materials used.*

Material	Type	Composition	Manufacturer	LOT number
everX Flow	Short fiber reinforced flowable composite for dentin replacement (Bulk shade)	ever X Flow is based on a combination of organic resin matrix and inorganic glass fibers and filler particles. The resin matrix contains Bis-MEPP 15-25%, TEGDMA 1-10% and UDMA 1-10%. The fillers are a mix of short E-glass fibers and particle fillers, mostly barium glass Average length of fibers 140µm diameter 6 µm. The total filler rate of ever X Flow is 70% in weight. % of fibers (w/w) 25%.	GC corporation Tokyo, Japan	1910162
Tetric N-flow	Bulk fill flowable light cured composite	Urethane dimethacrylate, Bis-GMA 27.8% Triethyleneglycol dimethacrylate - 7.3 Barium glass, ytterbium trifluoride, mixed oxide, silicon dioxide 63.8%	Ivoclar Vivadent AG Schan Liechtenstein	Y39762

Grouping:

The randomly non prepared 15 premolars were labeled as ***Group A***, teeth were intact without any cavity to serve as (negative control). After wide MOD cavities were prepared for the 45 premolars, They are grouped into three groups of fifteen each at random. ***Group B,*** the teeth with MOD cavities without any restoration (positive control). ***Group C***, the teeth will be restored with bulkfill flowable composite Tetric N flow bulk fill (Ivoclar Vivadent); and ***group D,*** the teeth will be restored with short fibers reinforced bulkfill flowable composite ever X Flow (GC).

Restorative steps:

Every prepared tooth was subjected to the following; washing with air water spray, Tofflemire matrix application then application of N etch 37% phosphoric acid. 30s for enamel and 15s for dentine followed with thorough water washing for 20 s then gentle air dryness for 5s only. application of futurabond M+ universal dental adhesive (VOCO Cuxhaven Germany) for 10 seconds with brush rubbing followed with air thinning for 2s, Then cured for 10 s (LED cordless 10 W APOZA Enterprise Co., Ltd.Taiwan) at 2000 mW/cm2 light intensity

Group C:

Immediately after curing of dental adhesive, Tetric N flow bulk fill was applied into the cavity as one layer to fill both proximal boxes and occlusal cavity leaving only 1mm from occlusal cavo-surface angle, then light curing according to manufacturer instructions (LED cordless 10 W APOZA Enterprise Co., Ltd.Taiwan) at 2000 mW/ cm2 light intensity. Superficial 1 mm of universal resin composite essential (GC corporation Tokyo, Japan) was filled and then cured according to manufacturer.

Group D everX Flow was filled as one layer to fill both proximal boxes and occlusal cavity leaving only 1mm from occlusal cavo-surface angle, then light cured with (LED cordless 10W APOZA Enterprise Co., Ltd.Taiwan) at 2000 mW/cm2 light intensity. superficial 1 mm of universal resin composite essential (GC corporation Tokyo, Japan) was filled and cured for 10s.

Every material is applied in accordance with the guidelines provided by the individual manufacturers. Following the completion of the restorations using Sof-Lex discs (3M ESPE), they were kept for a full day at 37°C in distilled water.

Fracture resistance assessment:

After one day of water storage, the specimens of four groups were subjected to fracture strength measuring; a universal testing machine subjected to a constant compressive axial loading at a crosshead speed of 1 mm/min. A smooth cylindrical head with a diameter of 5 mm was used to apply force to the occlusal slopes of the buccal and lingual cusps, which were in contact with the teeth's long axis. Each tooth's peak load to fracture was measured and its fracture strength was expressed in Newtons. Using SPSS 11.5 and a significance level of $\alpha = 0.05$, one-way ANOVA was used to analyze the data.

Failure pattern assessment:

The mode of fractures was then ascertained by two separate operators evaluating the fractured teeth, as:

Type I fracture; fracture of enamel only.

Type II fracture; enamel and dentin fracture with no root involvement.

Type III fracture; enamel and dentin fracture with root involvement.

Both type I and II considered as restorable fracture because they ending above the CEJ. Type III considered as non-restorable fracture because fracture below 1 mm from the CEJ.

RESULTS

I- Results of fracture resistance assessment:

The highest mean fracture load value was recorded in group A 1216.6 ± 352.2 followed with 1019.7 ± 164.8 for group D then 1013.3 ±

389.6 for group C while the lowest mean fracture load value 330.6 ± 201.5 was recorded in group B. A one-way ANOVA test showed that there was a statistically significant difference (p=0.00) between the groups. At the 0.05 level, the Tukey's post hoc test showed a significant difference between group B and all other groups.

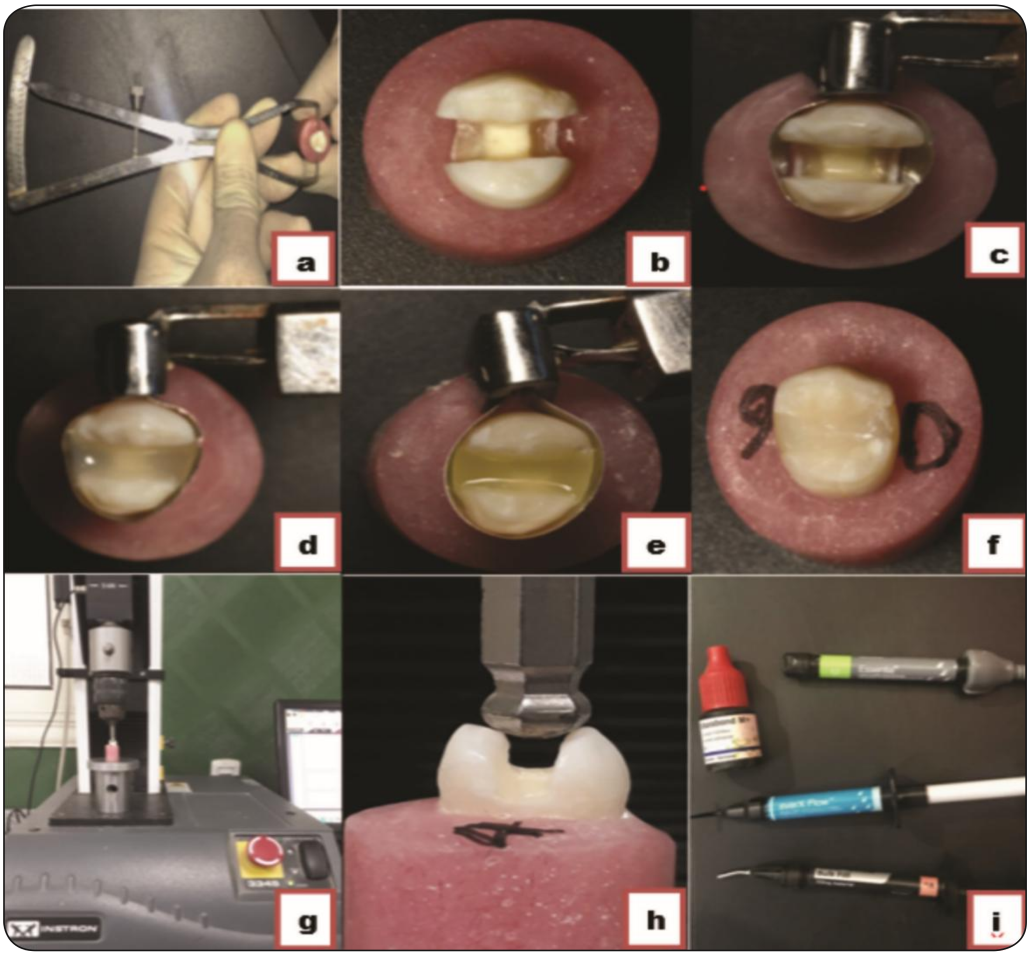

Fig. (1) ***Steps of samples preparations; a-*** dimensions of premolars, ***b***-MOD cavity , ***c***-matricing, ***d***-sample with Tetric N flow composite (group C), ***e***-sample with everX flow composite (group D), ***f***-superfacial layer of universal composite application, ***g***-universal testing machine, ***h***-cylindrical head on buccal and palatal slopes of premolar to measure fracture resistance, ***i***-different materials used.

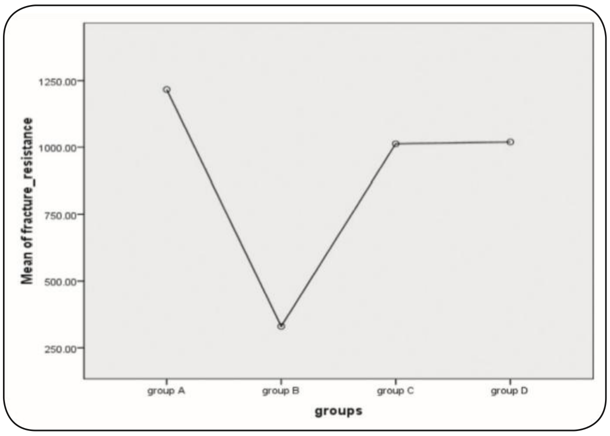

Fig. (2) Fracture resistance results.

II.Results of Failure pattern assessment:

The negative control (group A) predominantly fractured with restorable patterns 80% with the highest type I fracture. While the positive control (group B) predominantly fractured in non-restorable patterns 80% with the highest type III fracture. Fracture pattern for group C was 80% restorable fracture and for group D was 66.67 % restorable fracture.

Table (2) *Failure patterns and the proportion of each group's non-restorable and restoreable failures.*

Groups	Failure pattern			Percentage of restorable fracture	Percentage of non restorable fracture
	Enamel fracture	Enamel and dentine fracture	Enamel and dentine fracture with root fracture		
Group A	7	5	3	80%	*20%*
Group B	0	3	12	20%	80%
Group C	5	7	3	80%	*20%*
Group D	2	8	5	66.67%	33.33%

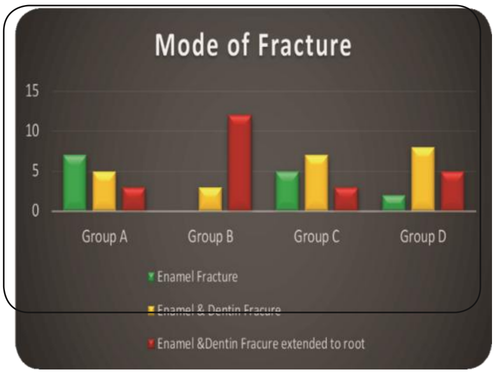

Fig. (3) The results of fracture mode

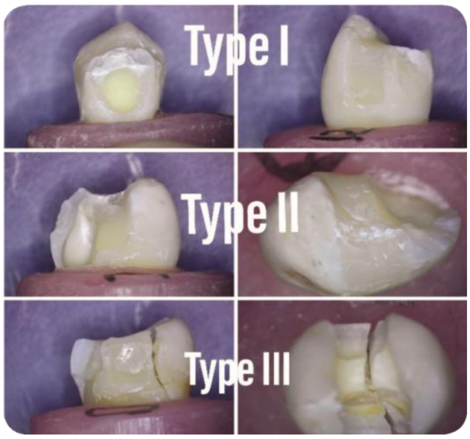

Fig. (4) The different modes of fractures

DISCUSSION

The purpose of this work was to compare the fracture resistance of bulk fill flow composite materials with a standardized MOD preparation restored with SFRC in order to assess the fracture resistance of premolar teeth. The weakening of tooth structures due to caries and large unsupported intracoronal restorations is the most important factor associated with crown fractures. In this investigation, we examined teeth with sizable MOD cavities, which are more likely to fracture because of construction in the cervical zone and cuspal inclination with high tensions on the cusps. Research shows that cavity preparation of any kind considerably lowers the resistance of teeth to fractures. [12,13]

The polymerization shrinkage of a resin composite, which can produce contraction forces and break the bond to the cavity walls or cause deformation on the surrounding tooth structure, is another factor that weakens teeth. This can result in tooth fracture. [14]

We decided to use the bulk fill flow composite in this investigation. Since there is a correlation between restoration weakening and polymerization shrinkage, some studies have demonstrated that bulk fill flow composites can lessen polymerization shrinkage in posterior teeth. Because of their low elastic modulus, they function as a flexible layer and may reduce cavity stresses during polymerization. This likely clarifies why teeth with MOD cavity preparations had increased fracture resistance thanks to the bulk fill flow composite. [15]

Because multiple studies have demonstrated that the fiber-reinforced composite (FRC) substructure supported the composite restoration and functioned as a crack-prevention layer, we employed an alternative bi-layered technique in this study called biomimetic composite structure, which is a restoration that includes both FRC and particulate filler composite PFC. In order to support the remaining tooth structure and increase the longevity of the finished biomimetic composite restoration, SFRC was developed as a dentine-replacing material (bulk base). [16]

Specialized fiber and polymer variety in the composition of SFRC materials results in a variety of improved mechanical and physical properties. The biomimetic restorative technique is a recommended direct restoration alternative that can be used with reliability for the coronal restorations of teeth with large cavities in high stress-bearing areas. It uses SFRC as a substructure with conventional composite overlying it.Because of the gradient concentration of its nanofillers, it also more evenly distributes the stresses brought on by polymerization shrinkage and load testing. [17]

Our findings indicate that flowable self-filled resin composites (SFRC) have a non-significantly higher fracture resistance than bulk fill flow composite resin. The lower polymerization shrinkage strain resulting from the fiber content could be the cause of this. Since each fiber acts as a crack stopper and transfers stress from the polymer matrix to stronger fibers, these fibers may have an isotropic reinforcing effect. In addition, SFRC has the same capacity to absorb stresses and release energy as dentin, which enhances mechanical performance by averting brittle failure and maintaining structural integrity.[5]

Many authors have shown in their clinical reports that using SFRC as a bulk base or core under direct composite restorations for posterior teeth can be considered an affordable and practical measure that could eliminate the need for extensive prosthetic treatment, confirming the previously mentioned laboratory data. [18,19] Several researchers found that adding SFRC to the interior cavity of posteriorly destroyed teeth that have been restored with thick PFC resin overlays does not improve the teeth's ability to withstand fractures, in contrast to the previously mentioned studies. They clarified that variations in overlay PFC composite thickness, loading configuration, and adhesive system were the causes of the disparity between their research and earlier investigations. [20-22]

The fracture resistance of SFRC was compared to various commercial composite resins by some authors, who concluded that it had superior fracture resistance and different physical properties from other tested bulk-fill or conventional composite materials.[23] However, in our study, we used both tested materials in a form that allowed for bulk fill to flow.

Because SFRC can withstand compressive static load, the failure patterns seen in this study revealed 66.7% restorable fracture in the SFRC group, which is significantly higher than in the cavitated non-filled group.These findings were consistent with those of authors who assessed the mechanical characteristics of SFRC in relation to other composite resin materials and concluded that the two primary elements responsible for SFRC's superior toughening capability over their competitors are the semi-inter penetrating network (IPN) structure and millimeter-scale short fiber. As a result, they suggested SFRC due to its increased toughness in high stress areas. [24,25]

According to the authors, bulk fill flow composites have evolved to have greater flexural strength, more flow, less shrinkage, and fewer cuspal strains. Restorable fracture was 80% for teeth restored with bulk fill flowable composite, which is comparable to the negative control group (sound, non-cavitated teeth). [26,27]

When SFRC (everX flow) restorations are used instead of bulk fill flow (Tetric N flow) restorations, the likelihood of non-restorable fracture increases. This could be because SFRC has a thicker consistency than bulk fill flow because of the additional short fibers, which weakens bonding resistance and encourages adhesive interface breakdown. [12]

CONCLUSION

Within the constraints of this investigation, it was possible to draw the conclusion that, with no discernible difference between the two tested materials, bulk fill flowable composite and short fiber reinforced flowable composite can both raise the fracture resistance of extensively prepared mesio-occluso-distal cavities of maxillary premolars to a limit close to that of sound non-prepared premolars.

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كفاءة مركب الحشو الكتلى القابل للتدفق والمقوى بالألياف القصيرة فى مقاومة الكسر للأسنان الضواحك ذات التجاويف الواسعة

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البريد الالكترونى للباحث الرئيسى **AHMEDALI@AZHAR.EDU.EG** :

الملخص :

الهدف :سعت هذه الدراسة إلي تقييم تأثير الحشو الكتلي القابل للتدفق والمقوي بالألياف القصيرة علي مقاومة الكسر للأسنان الضواحك ذات التجاويف الواسعة .

المواد والاساليب :في هذه الدراسة المعملية تم اختيار **60** سنة من الأسنان الضواحك العلوية وتخزينها في محلول الكلورامين. ثم تم تركيب الأسنان في كتل الاكريليك. تم تقسيم الأسنان بشكل عشوائي إلى **4** مجموعات **15** سنة لكل منها : المجموعة الأولي(أ)كانت الأسنان سليمة دون أي تجويف(مجموعة حاكمة سلبية)؛ تم إعداد تجاويف واسعة باستخدام مثقاب أسطواني مع اليد عالية السرعة في باقي المجموعات.
المجموعة الثانية(ب)تم عمل التجاويف الواسعة دون أي حشوات(مجموعة حاكمة إيجابية)؛ المجموعة الثالثة(ج)تم حشو الأسنان بمركب راتنجي قابل للتدفق؛ أما المجموعة الرابعة(د)فقد تم حشو الأسنان بمركب قابل للتدفق معزز بألياف قصيرة تم تخزين الأسنان بعد ذلك في الماء وعند درجة حرارة **37** درجة مئوية لمدة **24** ساعة ثم تم تعيين قوة مقاومة الكسر باستخدام جهاز الإنسترون وتسجيل القوة القصوى للكسر بالنيوتن لكل الأسنان وتم ملاحظة نوع الكسر بالمجهر . بعد ذلك تم تحليل النتائج إحصائيا

النتائج :نسبة حدوث الحق الجاف كانت **20%** فى المجموعة(ب) بينما كانت **0%** فى المجموعة(أ) شدة الألم الناتج عن الجراحة أقل في المجموعة (أ(عن المجموعة (ب(في يوم الجراحة و اليوم الثاني والرابع ما بعد الجراحة وثبت وجود فرق ذو دلالة احصائية. أما اليوم السابع والرابع عشر فلا يوجد فرق ذو دلالة احصائية بين المجموعتين. حمض الترانيكساميك ليس له أي تأثير على مقدار فتح الفم ومقدار التورم بعد جراحة ضرس العقل السفلى.

الخلاصه :إن مقاومة الأسنان الضواحك العلوية ذات التجاويف الواسعة للكسر قد تأثرت إيجابيا بشكل واضح عند حشوها بالحشو الكتلي القابل للتدفق والمقوي بالألياف القصيرة ولكن هذا التأثير الإيجابي كان مماثلا للأسنان المحشوة بالحشو الكتلي القابل للتدفق والغير مقوي بالألياف القصيرة

الكلمات المفتاحية :الحشو الكتلي القابل للتدفق ، الألياف القصيرة ، مقاومة الكسر ، الضواحك ذات التجاويف الواسعة ، قوى الضغط.