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ASSESSMENT OF SHEAR BOND STRENGH AND MARGINAL ADAPTATION OF ACTIVA VERSUS Fuji II LC IN PRIMARY MOLARS IN VITRO

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ABSTRACT

BACKGROUND: Restoration of decayed primary molars remains a key concern in pediatric dentistry, in which proper retention, marginal seal and pulp protection are very essential in preventing secondary caries. This necessitated the development of materials such as ACTIVA BioACTIVE Restorative (ACTIVA).

AIM OF THE STUDY: To assess the strength of the shear bond, bond mode of failure as well as marginal adaptation of ACTIVA in comparison to Fuji II LC when used in primary molars.

MATERIALS AND METHODS: The present research is an in vitro experimental, comparative study where sixty primary extracted molars were randomly divided into two groups (A and B); each group consisted of 30 specimens. Group A was used for measuring shear bond strength and group B for measuring marginal adaptation. Group A and group B were subdivided each into three subgroups. The first subgroup received ACTIVA with no pretreatment (I). Second subgroup received ACTIVA with adhesive (II). Third subgroup received Fuji II LC (III).

RESULTS: For shear bond strength, there is a significant difference between ACTIVA with adhesive (AII) and Fuji II LC (AIII) (p= 0.008). No significant differences were found between ACTIVA with no adhesive (AI) and ACTIVA with adhesive (AII) and between ACTIVA with no adhesive (AI) and Fuji II LC (AIII) {(p=0.824) and (p= 0.161) respectively}.

For marginal adaptation, there is a significant difference between ACTIVA with no adhesive (BI) and ACTIVA with adhesive (BII) and between ACTIVA with adhesive (BII) and Fuji II LC (BIII) {(p=0.020) and (p<0.0001) respectively}. No significant difference was found between ACTIVA with no adhesive (BI) and Fuji II LC (BIII) (p= 0.345).

CONCLUSION: ACTIVA with adhesive provided better results in comparison to ACTIVA without adhesive and Fuji II LC.

KEYWORDS: ACTIVA BioACTIVE Restorative, shear bond strength, marginal adaptation, Fuji II LC.

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INTRODUCTION

In recent years, the demand for tooth-colored restorations has dramatically increased because of their exceptional esthetics(1). In primary dentition, conventional composites, flowable composites as well as resin modified glass ionomer cements are the most often utilized restorative materials due to their excellent esthetics compared to amalgam restoration. These restorative materials adhere to tooth surface by various mechanisms(2). The adhesive property of these restorative materials is one of the most important characteristics that prevent microleakage(3).

Glass ionomer cements have been effectively employed as a conservative restoration in primary molars as they have many advantages including thermal expansion coefficient that is similar to natural teeth tissues, physicochemical adhesion to teeth structures, biocompatibility, fluoride release, good marginal adaptation and low shrinkage(4). Some types allow remineralization in adjacent interproximal caries(5). Resin modified glass ionomer restorations are widely used in pediatric dentistry. They have many disadvantages as their weak strength and inability to resist abrasion and wear. Moreover, resin modified glass ionomer restorations are difficult to work with because they are susceptible to moisture absorption during the early setting reaction and desiccation as the materials solidify. Although it was claimed that the presence of resin polymerization in modified materials reduced early moisture sensitivity, research has shown that when the materials were exposed to moisture, their properties changed substantially as decreasing their hardness and surface roughness(6,7).

Resin-modified glass ionomer cement (RMGIC) was recently produced by Pulpdent Corporation (Watertown, MA), and was called ACTIVA BioACTIVE Restorative which according to the manufacturer is enhanced with ‘shock-absorbing rubberized’ resin(8). Researchers examined some characteristics of this material which showed that ACTIVA has flexural strength comparable to that of packable composites and better than other resin modified glass ionomer cements(9,10).

In 2016, Bansal et al. reported that ACTIVA had the same wear resistance as composite resins(8). Bansal et al. claimed that the favourable mechanical behaviour drew attention away from the self-adhesive characteristics and the claimed bioactivity of ACTIVA (9). In 2017, May E et al. showed that ACTIVA's bioactivity is valid since it uptakes and releases fluoride which decreases caries formation at restoration margins(11). Furthermore, Mosallam el al. showed that ACTIVA revealed less fluoride release and more calcium release in comparison to light-cured resin reinforced glass ionomer restorations(12).

Many of the previously mentioned studies were mainly performed on permanent teeth. Moreover, composition of enamel of permanent teeth differs from that of primary teeth(13). Thus studies on primary dentition are needed to investigate the performance of ACTIVA especially regarding its bond strength and marginal adaptation to tooth structure.

Accordingly, the rationale of the study was to evaluate shear bond strength and marginal adaptation of ACTIVA with and without pretreatment in comparison to resin reinforced glass ionomer cements on primary molars. The null hypothesis of this study was that there are no differences between ACTIVA with or without pretreatment and resin reinforced glass ionomer cements when used in primary molars regarding shear bond strength and marginal adaptation.

MATERIALS AND METHODS

Study Design: The current research is an in vitro experimental, comparative study. It was performed at the Department of Pediatric Dentistry and Dental Public Health and the Department of Dental Biomaterials, Faculty of Dentistry, Alexandria University, Egypt. Ethics committee approved this research in the Faculty of Dentistry, Alexandria University under the code 0170-10/2020 (IRB NO 00010556-IORG0008839).

Sample Size Calculation: It was calculated using a 95 percent confidence level and an 80 percent study power. The mean and standard deviation (SD) of shear bond strength (SBS) for ACTIVA without enamel preconditioning is 17.62 (2.16) and 20.45 (3.21) MPa with preconditioning. Lower SBS values of 14.4 (5.93) MPa was reported when conventional RMGIC without pretreatment was applied. Using One Way ANOVA, sample size was computed to be 9 specimens for each group. This was increased to 10 specimens to make up for processing error. Total sample size= number per group × number of groups= 10 × 6 = 60 specimens. Sample size was based on Rosner’s method calculated by Gpower 3.0.10(14).

Inclusion criteria for human primary molars: Sound shed teeth or teeth extracted due to orthodontic purposes. The selected teeth had no caries or previous fillings, no cracks nor developmental anomalies. Teeth with fully resorbed roots were excluded as they could not be embedded in acrylic resin. All teeth were cleaned from blood and debris and were examined using a magnifying lens to select teeth that fulfill the inclusion criteria(15). The teeth were preserved in 10% formaldehyde at room temperature until required for use(16).

Sample grouping: The 60 primary molars fulfilling the inclusion criteria were randomly allocated into 2 main groups (A and B) based on the test used. Group A was subjected to shear bond strength test and group B for marginal adaptation test. Each main group was subdivided randomly into three sub-groups depending on the restorative material used. Teeth were assigned at random by a computer-generated list of random numbers(17).

For shear bond strength test: Group AI received ACTIVA (Pulpdent Corporation, USA) with no pretreatment, group AII received ACTIVA with adhesive (Xeno Select, Dentsply DeTrey, USA) and group AIII received Fuji II LC (SDI Corporation, Australia) with no pretreatment.

For marginal adaptation test: Group BI received ACTIVA with no pretreatment, group BII received ACTIVA with adhesive and group BIII received Fuji II LC with no pretreatment.

1. Shear bond strength test:

The roots of primary molars were inserted in acrylic resin(18). Silicon carbide paper (up to #1000 grit) was used to ground the buccal surface of molars and produce a flat surface of enamel(19). A teflon mold was located on the buccal surface of all tooth specimens. Each tested material was placed in the central hole of the mold (3mm diameter and 3mm height)(20). The material was placed based on the manufacturers' instructions and was light cured for 20 seconds(21).

Sub-group AI received ACTIVA with no pretreatment (no adhesive). The restoration was placed in the Teflon mold and light cured for 20 seconds using an LED light cure (3M Corporation, USA). Sub-group AII received ACTIVA following the application of a self-etch adhesive. The adhesive was applied twice to evenly wet the teeth, gently agitated for 20 seconds, then dried for 5 seconds to allow the solvent to evaporate completely and then was light cured for 20 seconds. The restoration that was placed in the Teflon mold was light cured for 20 seconds using a LED light cure. Sub-group AIII received Fuji II LC with no pretreatment. The restoration that was placed in the Teflon mold was light cured for 20 seconds using an LED light cure.

Following the restoration placement, the tooth was separated from the teflon mold then it was stored in saline solution at 37 °C. After that all samples were thermocycled and stored for another 28 days in saline solution at 37°C before testing for the strength of shear bond which was done using universal testing machine (Instron, High Wycombe, UK)(22).

2. Marginal adaptation test:

The primary molars were embedded in acrylic resin(18). A 3mm diameter and 1.5mm depth semi-spherical cavity was prepared on the occlusal surface to standardize cavity dimensions; this cavity was prepared using a spherical round bur. A stereo microscope under x25 magnification was used to measure the exact cavity dimensions(23).

Restorations of sub-groups BI, BII and BIII were applied as previously mentioned. After placing the restoration, excess material above cavity margins was ground away using silicon carbide paper #1000 then all the specimens were polished wet on felt with the particles of aluminum oxide before being flushed with pressured water to eliminate remaining debris from the surface. The specimens were kept in saline solution at 37 °C for 1-2 hours and a first marginal assessment was performed. After that the specimens were thermocycled before undergoing a second marginal assessment. The specimens were then kept in saline solution at 37 °C for 28 days before the final marginal assessment was performed (22). All specimens were thermocycled for 1500 cycles in a water bath between 5°C and 55°C, simulating a year and a half in the oral cavity (24,25).

Outcome Evaluation:

Shear bond strength test:

The shear bond strength was computed in megapascal (MPa) in accordance to the following equation: Shear bond strength= fracture load (Kg) / surface area of the disc (cm^2) where area of the disc = πr^2. Then shear bond strength value Kg/cm^2 was converted to MPa by multiplying with 0.09807(26).

Mode of failure test:

Following the shear bond strength testing, all specimens were assessed by one trained examiner using an optical microscope (Stereomicroscope) at x25 magnification for the mode of failure which was identified as adhesive, cohesive or mixed (adhesive and cohesive)(27).

Marginal adaptation test:

Stereomicroscope was used to assess marginal adaptation. The cavity diameters of all tooth specimens were measured before thermocycling then the gaps formed were measured after thermocycling altering the cavity diameter. Therefore, the restoration's linear wall to wall contraction was computed as a percentage of the cavity diameter(21).

Statistical analysis:

Normality was checked using Shapiro Wilk test, box plots and descriptives. Shear Bond Strength and marginal adaptation scores were not normally distributed and presented using Mean, Standard deviation (SD), Median, Inter Quartile Range, Minimum and Maximum. Mode of failure was presented using count and percent. Groups were compared using Kruskal Wallis Test followed by post hoc test with Bonferroni correction. Pearson Chi Square test was used to compare the groups regarding mode of failure. Intra-examiner reliability regarding mode of failure was assessed using Cohen's Kappa Coefficient. The significance level was fixed at 0.05 *p* value, all the tests were two tailed. Statistical Package for the Social Sciences (SPSS) for Windows version 23 was used to analyze the data.

RESULTS

Shear Bond Strength

The mean shear bond strength of ACTIVA with no adhesive (AI), ACTIVA with adhesive (AII) and Fuji II LC (AIII) were 4.49(2.41), 5.27(2.04) and 2.23(1.11) Mpa respectively with significant differences between the 3 groups where (*p*=0.009). ACTIVA with adhesive had the highest shear bond strength followed by ACTIVA without adhesive, whereas Fuji II LC had the lowest shear bond strength. The Post Hoc Test done indicated significant differences between ACTIVA with adhesive (AII) and Fuji II LC (AIII) (p_3= 0.008). No significant differences were found between ACTIVA with no adhesive (AI) and ACTIVA with adhesive (AII) and between ACTIVA with no adhesive (AI) and Fuji II LC (AIII) {(p_1=0.824) and (p_2= 0.161) respectively} (Table 1).

Mode of Failure

Intra examiner reliability was assessed by Kappa statistics, which presented substantial agreement (K=0.80). The results of failure modes of ACTIVA with no adhesive (AI) showed that 80% (8 specimens) had adhesive failure and 20% (2 specimens) had mixed adhesive-cohesive failure, whereas ACTIVA with adhesive (AII) showed 50% (5 specimens) adhesive failure and the other 50% (5 specimens) had mixed adhesive-cohesive failure. The mode of failure of Fuji II LC (AIII) was only adhesive failure 100% (10 specimens). The results indicated significant differences between the 3 groups where (*p*=0.029).

The Post Hoc Test done indicated significant differences between ACTIVA with adhesive (AII) and Fuji II LC (AIII) (p_3= 0.033). No significant differences were found between ACTIVA with no adhesive (AI) and ACTIVA with adhesive (AII) and between ACTIVA with no adhesive (AI) and Fuji II LC (AIII) {(p_1=0.350) and (p_2= 0.474) respectively} (Table 2).

Marginal Adaptation

The mean wall to wall contraction of ACTIVA with no adhesive (BI), ACTIVA with adhesive (BII) and Fuji II LC (BIII) were 1.94(1.65), 0.29(0.20) and 4.19(3.01) um respectively with significant differences between the 3 groups where (*p*<0.0001). ACTIVA with adhesive had the highest marginal adaptation followed by ACTIVA without adhesive, whereas Fuji II LC had the lowest marginal adaptation. The Post Hoc Test done indicated significant differences between ACTIVA with no adhesive (BI) and ACTIVA with adhesive (BII) and between ACTIVA with adhesive (BII) and Fuji II LC (BIII) {(p_1=0.020) and (p_3<0.0001) respectively}. No significant difference was found between ACTIVA with no adhesive (BI) and Fuji II LC (BIII) (p_2= 0.345) (Table 3) (Fig 1, 2 and 3).

Figure 1: Group BI (ACTIVA with no adhesive); figure A showing diameter of the filling mesiodistally before thermocycling and figure B showing gaps formed around the filling after thermocycling.

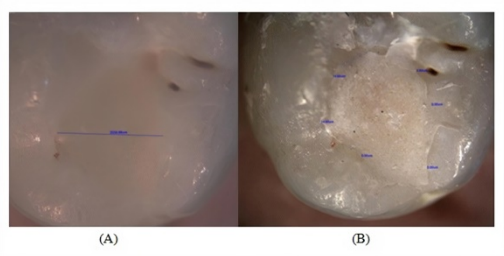

Figure 2: Group BII (ACTIVA with adhesive); figure A showing diameter of the filling before thermocycling mesiodistally and figure B showing gaps formed around the filling after thermocycling.

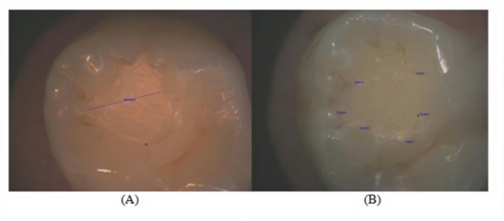

Figure 3: Group BIII (Fuji II LC); figure A showing diameter of the filling before thermocycling mesiodistally and figure B showing gaps formed around the filling after thermocycling.

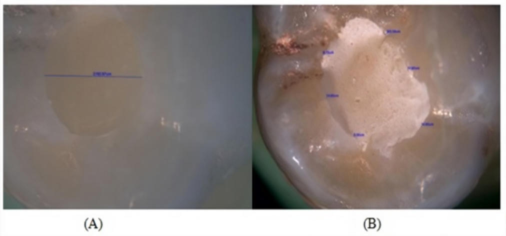

Table 1: Comparison of Shear Bond Strength between the experimental groups

	Activa with no adhesive(AI) (n=10)	**Activa with adhesive(AII) (n=10)**	**Fuji II LC(AIII) (n=10)**
Mean (SD)	4.49 (2.47)	5.27 (2.04)	2.23 (1.11)
Median (IQR)	4.98 (4.56)	5.97 (4.12)	2.22 (1.25)
Min - Max	1.21 – 7.04	1.94 – 7.21	0.46 – 4.44
Test (*P* value)	9.370 (0.009)		
Post hoc test	p_1=0.824, p_2= 0.161, p_3= 0.008		

*Statistically significant difference at *p* value ≤0.05
p_1: Comparison between Activa with no adhesive (AI) and Activa with adhesive (AII).
p_2: Comparison between Activa with no adhesive (AI) and Fuji II LC (AIII).
p_3: Comparison between Activa with adhesive (AII) and Fuji II LC (AIII).
(n) Sample size number for each group.

Table 2: Comparison of Mode of Failure between the Shear Bond Strength experimental groups

	Activa with no adhesive (AI) (n=10)	**Activa with adhesive (AII) (n=10)**	**Fuji II LC (AIII) (n=10)**
	N (%)		
Adhesive	8 (80%)	5 (50%)	10 (100%)
Mixed	2 (20%)	5 (50%)	0 (0%)
Test (*P* value)	7.081 (0.029)		
Post hoc test	p_1=0.350, p_2= 0.474, p_3=0.033		

*Statistically significant difference at *p* value≤0.05
p_1: Comparison between Activa with no adhesive (AI) and Activa with adhesive (AII)
p_2: Comparison between Activa with no adhesive (AI) and Fuji II LC (AIII)
p_3: Comparison between Activa with adhesive (AII) and Fuji II LC (AIII)
(n) Sample size number for each group.

Table 3: Table 3: Comparison of Linear Wall to Wall Contraction between the experimental groups

	Activa with no adhesive (BI) (n=10)	**Activa with adhesive (BII) (n=10)**	**Fuji II LC (BIII) (n=10)**
Mean (SD)	1.94 (1.65)	0.29 (0.20)	4.19 (3.01)
Median (IQR)	1.12 (2.42)	0.36 (0.44)	3.62 (6.19)
Min - Max	0.40 – 5.16	0.00 – 0.49	0.99 – 8.42
Test (*P* value)	18.904 (<0.0001)		
Post hoc test	p_1=0.020**,** p_2= 0.345, p_3<0.0001		

*Statistically significant difference at *p* value ≤0.05
p_1: Comparison between Activa with no adhesive (BI) and Activa with adhesive (BII)
p_2: Comparison between Activa with no adhesive (BI) and Fuji II LC (BIII)
p_3: Comparison between Activa with adhesive (BII) and Fuji II LC (BIII)
(n) Sample size number for each group.

DISCUSSION

Pediatric dentists always face a challenge when using glass ionomer restorations due to weak bond strength and gaps formation(28). The following laboratory research investigated characteristics that is pertinent to the clinical usage and performance of ACTIVA, restorative materials with claimed bioactivity in comparison to other glass ionomer restorations. In the present study, ACTIVA was tested to assess its shear bond strength when used on buccal surfaces of primary molars as well as its marginal adaptation in a semi-spherical cavity on the occlusal surface of primary molars. There have been no sufficient studies testing the current data(21).

Thermocycling is an in vitro method in which the restoration and the teeth are exposed to temperatures and conditions comparable to those found in the oral cavity. Thermocycling stresses the bonding between the resin and the teeth, as well as depending on the adhesive technique used, the bond strength might be impaired(29). However, according to Gale and Darwell (30), determining the change in the temperatures in the oral cavity is challenging since there are differences in temperature across different individuals and within the same person depending on the position in the mouth cavity. Due to a lack of agreement in the literature on thermocycling standards, the International Organization for Standardization (ISO) (ISO/TS, 2015) proposed a standardized protocol with the criteria of thermocycling between 5°C and 55°C with a dwell time of 30s as a method of universal standardization. This approach was chosen for this investigation because it was consistent with previous research of various restorations(24).The number of cycles done in this study were 1500 cycle for all specimens which simulate a year and half in the oral cavity(25,31).

In the present study, the results revealed that mean shear bond strength of ACTIVA with adhesive (5.27Mpa) produced slightly better results than ACTIVA with no adhesive (4.49 Mpa), whereas Fuji II LC showed the lowest mean shear bond strength (2.23 Mpa). The Post Hoc Test done between groups showed no significant differences between ACTIVA with no adhesive (AI) and ACTIVA with adhesive (AII). It also showed no significant differences between ACTIVA with no adhesive (AI) and Fuji II LC (AIII). However, there was a significant difference between ACTIVA with adhesive (AII) and Fuji II LC (AIII). The significant difference between ACTIVA with adhesive (AII) and Fuji II LC (AIII) highlights the importance of self-etch adhesive bonding before placing restorations. The mode of failure differences among the 2 groups supported the shear bond strength results as ACTIVA with adhesive (AII) showed many mixed adhesive-cohesive failure modes, whereas all specimens of Fuji II LC (AIII) showed adhesive mode of failure.

Nijhawan et al. in 2019(32), compared the shear bond strength of ACTIVA to that of the traditional composite. In this study enamel was pretreated using a method other than the one used in the current study. The results showed that ACTIVA had better shear bond strength than traditional composite when enamel was pretreated with both bur and laser. According to Nijhawan et al., these findings were because ACTVA includes antimicrobial phosphate acid group that increase the interface between the resin and reactive glass fillers, as well as the interface with the teeth structure.

The findings of Nanavati el al. in 2021(33) are consistent with the current study's findings as ACTIVA showed higher shear bond strength when compared to the conventional glass ionomer cements on primary molars due to the formation of mineral apatite crystals. Moreover the findings of Benneti et al. in 2019(21) are also in agreement with outcomes of the present study, where ACTIVA indicated a higher bond strength than Fuji II LC, and that all restorations were lost if no self-etch adhesive was used with ACTIVA.

Regarding the mode of failure, both ACTIVA with and without adhesive showed a mixture of adhesive and mixed adhesive-cohesive mode of failures, whereas Fuji II LC showed only adhesive mode of failure proving that both ACTIVA with and without adhesive had better shear bond strength in comparison to Fuji II LC(27).

The findings of Calvo et al.(34) are in agreement with the present results and claim that 80% of glass ionomer cements showed an adhesive mode of failure. However, a study by Singh et al.(35) revealed that the mode of failure of glass ionomer cements mostly mixed (cohesive inside the material), implying that the obtained outcomes didn’t reflect the strength of the bonded interface but rather the material's intrinsic weakness.

The present study tested the marginal adaptation of ACTIVA with and without adhesive in comparison to glass ionomer restorations. This test was done by measuring the cavity diameter of all tooth specimens before and after thermocycling. The Post Hoc Test done between the groups showed a significant difference between ACTIVA with no adhesive (BI) and ACTIVA with adhesive (BII).The findings highlight the importance of using self-etch adhesive bonding prior to restoration placement. The test also revealed that although there were no significant differences between ACTIVA with no adhesive (BI) and Fuji II LC (BIII), a significant difference was revealed between ACTIVA with adhesive (BII) and Fuji II LC (BIII).The data claims that ACTIVA is a bioactive composite that combines the benefits of glass ionomers with the strength and resilience of a resin matrix that won’t crack or crumble as reported by Banon R(36). However, the findings of the present study contradicts the outcomes of the study of Benneti et al.(21), which showed that Fuji II LC had the best marginal adaptation while ACTIVA with and without adhesive had the worst marginal adaptation. The different outcome between the 2 studies is possibly due to different handling and manipulation of materials.

On the other hand, Omidi et al. in 2018(37), measured the microleakage of ACTIVA with and without adhesive and Fuji II LC using die penetration, and study showed that microleakage of Fuji II LC was much higher than that of ACTIVA with and without adhesive which could be considered in agreement of results of the current study since microleakage is related to marginal adaptation.

Although results from in vitro studies could be a useful tool in providing important information to be used clinically, they still cannot represent the in vivo situations which involve a wide range of oral variables. Difficulty in recreating the complex array of conditions present in the oral environment through thermocycling could be considered a limitation to the current study. The present study was conducted on enamel surface only, which urges the need of further studies on dentin surface.

The findings of the present study indicated a significant difference between ACTIVA with adhesive and Fuji II LC. Where ACTIVA with adhesive showed the highest shear bond strength. Considering marginal adaptation ACTIVA with adhesive indicated the least linear wall to wall contraction proving the best marginal adaptation. Moreover, results indicated no significant difference between ACTIVA without adhesive and Fuji II LC which point out the importance of using an adhesive with ACTIVA. The most important implication of the study findings is that it's recommended to use ACTIVA with adhesive which proved to be a promising restoration in primary teeth. The null hypothesis has therefore been rejected as findings revealed significant differences between the 2 restorative materials.

CONCLUSION

The following conclusion was drawn within the limitations of this *in vitro* study:

ACTIVA with adhesive had better shear bond strength and marginal adaptation in comparison to ACTIVA without adhesive and Fuji II LC.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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