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The Effect of Different Caries Removal Methods on The Surface Hardness and Micro-tensile Bond Strength

Farklı Çürük Temizleme Yöntemlerinin Yüzey Sertliği ve Mikrogerilme Bağlanma Dayanımı Üzerine Etkisi

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ABSTRACT

Objective: This study aims to evaluate the effects of five different caries removal methods on caries removal effectiveness according to microhardness and micro tensile bond strength values.
Materials: In this study, for the microhardness test, micro-tensile bond strength test (n = 10) SEM analysis (n = 2), and a total of 72 human molar teeth were used. Caries lesions were removed with conventional (steel bur, ceramic bur, polymer bur) methods, chemomechanical method (Brix-3000), and fluorescence-aided caries excavation method (Siroinspect). Then, teeth were sectioned longitudinally through the cavity center and were subjected to the microhardness test, micro tensile test, and SEM atomic analysis. Statistical analyses were performed using one-way ANOVA and Duncan post-hoc tests.
Results: A statistically significant difference was found between all caries removal methods and measurement levels at certain distances from the cavity floor (0, 25, 50, 75 µm) (P <.05). As a result of the microhardness test, the group in which the fluorescence-aided caries removal method was applied was significantly higher than those in which the other caries removal methods were applied (P <.05). According to the results of the micro tensile bond strength test, a significant difference was found between the groups where Siroinspect, BRIX-3000, steel bur caries removal methods were applied and the groups of polymer bur and ceramic bur (P <.05).
Conclusion: According to the results obtained from this study, the Siroinspect device in the category of FACE method can be a reliable alternative to traditional caries removal methods.
Keywords: Caries removal, Dentine, Microhardness, Micro tensile bond strength, SEM

ÖZ

Amaç: Bu çalışma, mikrosertlik ve mikro çekme bağlanma mukavemeti değerlerine göre beş farklı çürük giderme yönteminin çürük giderme etkinliği üzerindeki etkilerini değerlendirmeyi amaçlamaktadır.
Gereçler: Bu çalışmada mikrosertlik testi için mikro çekme bağlanma dayanımı testi (n=10) SEM analizi (n=2) ve toplam 72 adet insan azı dişi kullanıldı. Çürük lezyonları geleneksel (çelik frez, seramik frez, polimer frez) yöntemler, kemomekanik yöntem (Brix-3000) ve floresans destekli çürük kazı yöntemi (Siroinspect) kullanılarak uzaklaştırıldı. Daha sonra dişler kavite merkezinden uzunlamasına kesilerek mikrosertlik testi, mikro çekme testi ve SEM atom analizine tabi tutuldu. İstatistiksel analizler, tek yönlü ANOVA ve Duncan post-hoc testleri kullanılarak yapıldı.
Bulgular: Tüm çürük giderme yöntemleri ile kavite zemininden belirli mesafelerde (0, 25, 50, 75 µm) ölçüm seviyeleri arasında istatistiksel olarak anlamlı bir fark bulundu (P <.05). Mikrosertlik testi sonucunda floresans destekli çürük giderme yönteminin uygulandığı grup, diğer çürük giderme yöntemlerinin uygulandığı gruba göre anlamlı derecede yüksekti (P<.05). Mikro çekme bağlanma mukavemeti testi sonuçlarına göre Siroinspect, BRIX-3000, çelik frez çürük giderme yöntemlerinin uygulandığı gruplar ile polimer frez ve seramik frez grupları arasında anlamlı fark bulundu (P<.05).
Sonuç: Bu çalışmadan elde edilen sonuçlara göre FACE yöntemi kategorisinde yer alan Siroinspect cihazı, geleneksel çürük giderme yöntemlerine güvenilir bir alternatif olabilir.
Anahtar Kelimeler: Çürük giderme, Dentin, Mikrosertlik, Mikro çekme bağlanma mukavemeti, SEM

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INTRODUCTION

The principle of conservative tooth cavity preparation has gained popularity with the development of bonding systems that make it sufficient to remove minimal tooth tissue to ensure retention and resistance form. [1,2] According to the conservative approach, the path followed in the treatment of caries lesions, to prevent the progression of the caries lesion, is the removal of infected dentin areas, the protection of affected tissues, and the restoration of endurance and function to continue.[3,4] Traditionally, caries tissue is removed by rotary systems, milling cutters, or sharp-edged hand tools using mechanical principles.[5] It is reported that the traditional method can cause pulp injuries due to excessive tooth removal of hard tissue. In addition, some disadvantages cause discomfort to patients during treatment, such as pain, loud noise, heat generated during preparation, vibration, and dentin sensitivity.[5,6]

To avoid these disadvantages, different techniques have been developed that include air-abrasions, ultrasonic instrumentation, sono-abrasions, photoablation, and chemomechanical caries removal methods that can be an alternative to the traditional method.[7] Brix-3000, produced in 2012 (Brix S.R.L. Argentina), is one of the chemomechanical caries removal agents containing the papain-based proteolytic enzyme derived from leafy latex and green papaya fruits. Because it contains antiprotease (α-1 antitrypsin), the agent that has proteolytic activity on collagen, it does not act on healthy tissues. Advantages of Brix-3000 include the fact that it can easily remove collagen fibrils in caries tissue, slightly dissolve in oral fluids, does not require a cold chain for storage, and has an antibacterial and antifungal effect, as well as an antiseptic effect.[8]

In the caries-removing method (FACE) with the help of fluorescence, a newly developed system, purple light is applied to the cavity, which allows the hard tissues of the tooth to gain autofluorescent properties while cleaning caries. Under this purple light, the solid tooth hard tissue is green, and the caries tissue is orange-green.[9] SIROInspect ® (Sirona Dental Systems GmbH, Germany), using a fluorescence emitting device approximately 405 nm long, the operator uses glasses to see the fluorescence in the dentin. SIROInspect diagnostic glasses filter wavelengths are shorter than 500 nm while making wavelengths higher than 500nm visible. [10]

Looking at the studies carried out so far, the number of studies in which the effectiveness of the traditional method, chemomechanical method, and transillumination methods in removing caries tissue were evaluated together is quite small. The purpose of this study;

** Determine the effectiveness of different caries removal methods (traditional, chemomechanical, and transillumination) in caries removal using a microhardness test,*

** Ability to determine the bonding strength of composite resin to the remaining dentin tissue,*

** Perform surface analysis on samples representing groups*.

MATERIAL AND METHOD

This study was approved by the Atatürk University Faculty of Dentistry Deanery Ethics Committee. (11.01.2018/12). The study included 72 human molar teeth with occlusal caries that had just been pulled or waited no more than six months after extraction. Tissue residues and attachments on the teeth were cleaned and stored in 0.1% thymol solution until the initiation of the experiment to prevent dehydration and fungal growth. Teeth with no restoration or fissure sealant were not included in the study. The highest values obtained using a type diagnostic Pen (KaVo, Bieberach, Germany) were recorded to determine the teeth to be included in the study. For fissure caries and flat surface caries, teeth with a numerical value of 25 and above, which is a value indicating that the demineralization shown by the device is intense, were reserved for the study. Teeth with a value of 0-12 were determined as a control group. In addition, those whose distance of the caries lesion to the pulp chamber was more than 1mm were included in the study. Methods of removal of caries used in the study are given in Table 1. (A consent form was not obtained because no study was conducted on the patient)

Table 1. Methods of Caries Removal

Caries removal methods	Trade name / Lot No	Manufacturer
Steel round bur method	Steel burs /E11.008	Edenta, Schaanwald/Liechtenstein
Ceramic round bur method	CeraBur / 353594	Komet Dental, Lemgo/Germany
Polymer round bur method	Smart burs II / 52003	SS White, Lakewood/ USA
Chemo-mechanical method	BRIX-3000/ L27V10/20	BRIX Medical Science/Argentina
FACE (fluorescent aid caries removal/siroinspect)	Siroinspect / 0818	Sirona The Dental Company/Switzerland

Removal of Caries Tissue

The samples included in the study were divided into 6 groups randomly according to the methods of removal of caries. (n=10) After the enamel tissue of the decayed teeth in the control group was removed by diamond round bur, cavities with a depth of 2/3 of the dentin were prepared with the help of a diamond fissure bur aerator.

Caries removal with steel bur

In the removal of caries with steel round bur, diamond bur was used at high speed with the help of an aerator and then at low speed with the help of a steel round bur micromotor to reach the caries lesion regardless of the size of the lesion. Dentin caries in the teeth were removed by the operator according to tactile (obtaining a hard surface in dentin according to whether a blunt probe is not snapped on the floor of the cavity or the absence of a pull-back feeling) and visual (no color distortion /change) criteria until a “no caries” result was given as Kidd et al.[11] stated.

Caries removal with ceramic bur

After enamel removal, dentin caries in the teeth were removed by the operator until a “no caries” score was given according to tactile criteria (obtaining a hard surface in the dentin according to the absence of a non-sharp probe) and visual criteria (lack of any discoloration/change).

Caries removal with polymer bur

After removing enamel as indicated in the previous method, dentin caries in the teeth were removed in circular movements towards the periphery, starting from the center following the manufacturer's instructions. The caries removal process was terminated when the bur blades did not wear and remove the tissue. The presence of carious tissue / hard tissue at the base of the cavity was checked with a blunt probe.

Caries removal with the help of the transillumination method

In this method, after removing the enamel as mentioned, the reflector light was turned off and the cavity was illuminated by fluorescence light (Siroinspect device, 405 nm, Sirona the Dental Company, Switzerland). The cavity was examined with the help of a filter that passes light over a wavelength of 500 nm. The textures in the orange/red fluorescence parts were removed with the help of a steel round bur. The caries removal continued until only green areas were observed in the cavity. Brown/black areas emitting green fluorescence were left with affected dentin/caries free.

Removal of caries by chemomechanical method

Before the Brix 3000 gel application, the enamel tissue was removed with a high-speed aerator. After moistening the caries area by the manufacturer's instructions, BRIX-3000 gel was placed in the cavity with a blunt-tipped handpiece and left for 2 minutes. This procedure was performed repeatedly until the caries tissue was completely removed.

For each caries removal method, to achieve standardization, a bur was changed in each example. For each caries removal method, samples were checked again by two independent observers, except for the operator, whether there was a caries at the base of the cavity. Dentin tissue was examined for color and hardness. It was decided that areas of dark yellow or light brown color and where the end of the probe penetrated the cavity were caries dentin tissue, and these areas were removed. Dark hard areas where the end of the probe did not penetrate the dentin tissue were left in the cavity. Two observers were calibrated for ICDAS II criteria and radiographic evaluation. For the calibration of ICDAS II criteria, the 90-minute e-learning program available on the organization's website was used.

Preparation of Samples

Under the water-cooled low-speed fine-cutting device (Isomet 1000, Buehler, Lake Bluff, IL, USA), samples were cut in the bucco-lingual direction. Half of the 20 samples in each group obtained by dividing the 10 teeth in each group embedded in the acrylic resin were separated for microhardness measurements and the other half for micro tensile measurements. Samples were polished with silicon carbide grit papers (Grit flex, Italy) 800, 1000, 1200, 1500, and 2000 and diamond paste (Diamond polish, Ultradent, USA) with a particle size of 1 µm. Microhardness measurement was performed using the microhardness device (Vickers-Fm800 (Tokyo/Japan). (Four measurements were taken from each sample).

Micro tensile Bonding Strength Test

After the occlusal enamel tissue of the samples was removed with the aid of a cutting device (Isomet 1000, Buehler, Lake Bluff, IL, USA) the universal bonding agent Clearfil Universal Bond (Kuraray, Noritake Dental Inc. Japan) was applied to the entire dentin surface according to the manufacturer's instructions light cured for 10 seconds. Composite resin (Universal Restorative 200, 3M ESPE, USA) was placed on the surface of the dentin in 2 layers with a thickness of 3-4 mm, and each layer was polymerized for 20 seconds. The teeth were sliced 1 mm thick and rod-shaped samples with an average cross-sectional area of 30 pieces of 1±0.2 mm^2 were obtained in each group. The tensile force was applied to the samples by using the universal testing device (Instron 8874; Instron Corp. Canton, Mass, 1 mm/min) until they broke.

SEM Evaluation

Two samples from each group were used for SEM measurement. Prepared samples were immediately placed in a 2.5% glutaraldehyde solution (Merck KGaA, Darmstadt, Germany) with a pH of 7.4 buffered with 0.1 M sodium cacodylate (Sigma-Aldrich, USA) to provide fixation and stored at 4°C for at least 12 hours. After fixation, samples were washed 3 times with 0.2 M sodium cacodylate buffer with a pH of 7.4 for 20 minutes and then with distilled water for 1 minute. It was then dehydrated in increased concentrations of ethanol solution (Merck KGaA, Darmstadt, Germany). For this, it was kept in 25%, 50% and 75% ethanol for 20 minutes, in 95% ethanol for 30 minutes and in 100% ethanol for 60 minutes. Samples were polished with silicon carbide grit papers (Grit flex, Italy) 800, 1000, 1200, 1500, and 2000 and diamond paste (Diamond polish, Ultradent, USA) with a particle size of 1 µm.

Samples were examined in the SEM device (Zeiss-GeminiSEM, Germany) with a voltage of 10 kV, x1000 and x4000 magnification.

Statistical Analysis

According to the Kolmogorov-Smirnov test, all of the samples showed normal distribution. Comparison of microhardness values of samples obtained using different caries removal methods one-way ANOVA and Duncan test were used to determine differences between groups.

A comparison of the values obtained in MPa as a result of the microtensilee bonding strength test of the samples belonging to the groups was performed using a one-way ANOVA test. The Duncan test was used as the Post hoc test.

RESULTS

Microhardness values measured in the control group (0 µm) were statistically significantly lower compared to microhardness values at 25 µm (P<.05). Microhardness values at 25 µm were significantly lower than microhardness values at 50 µm and 75 µm, and significantly higher than microhardness values at 0 µm (P<.05).

According to microhardness test values at 0 µm, 25 µm, 50 µm, and 75 µm were statistically significantly different in the steel round bur, ceramic round bur, polymer round bur, BRIX-3000 and Siroinspect groups (P<.05). (Table 2)

Table 2. Microhardness (VHN) and standard deviation values for different caries removal methods

Groups	Microtensileee bonding strength values (MPa)
Control (Group 1)	34.31 ± 6.67^{A}
Steel round bur (Group2)	23.59 ± 4.37^{BC}
Ceramic round bur (Group3)	23.13 ± 5.27^{C}
Polymer round bur (Group 4)	20.05 ± 4.74^{D}
BRIX-3000 (Group 5)	26.07 ± 5.26^{B}
Siroinspect (Group 6)	24.69 ± 4.74^{BC}

Different letters indicate a statistically significant difference

The bottom of the cavity (0 µm) microhardness values after the control group, second highest microhardness values (38,00 ± 4,83) were obtained from the Siroinspect group. These values were significantly higher than steel burs, ceramic burs, polymer burs, and Brix 3000 groups (P<.05). There was no significant difference between the steel bur and ceramic bur groups (P>.05). The polymer bur and Brix 3000 groups were found to be significantly higher compared to the microhardness values (P<.05).

In measurements at 25 µm, after the control group, the second highest microhardness values (51,18 ± 2,65) were observed in the Siroinspect group and were found to be significantly higher than the steel bur, ceramic bur, polymer bur, BRIX-3000 groups (P<.05). It was found that the microhardness values of the steel bur group were significantly higher compared to the ceramic bur, polymer bur, and BRIX-3000 groups (P<.05). Ceramic bur was found to be significantly higher than polymer bur group (P<.05)

In measurements at 50 µm, after the control group, the second highest microhardness values (57.88 ± 1.86) were observed in the Siroinspect group and were also significantly higher compared to the steel bur, ceramic bur, polymer bur, BRIX-3000 groups (P<.05). It was found that the microhardness values of the steel bur group were significantly higher compared to the ceramic bur, polymer bur, and BRIX-3000 groups (P<.05). Microhardness values in the ceramic bur group were significantly higher than those in the polymer bur and Brix 3000 groups. (P<.05)

In 75 µm measurements, after the control group, the second highest microhardness values (62.22 ± 1.69) were observed in the Siroinspect group and were also significantly higher compared to the steel bur, ceramic bur, polymer bur, BRIX-3000 groups (P<.05). While there is no significant difference between the steel bur and ceramic bur groups

(*P*>.05), polymer bur and BRIX-3000 groups were found to be significantly higher compared to microhardness values (*P*<.05).

Micro tensile Bonding Strength Test Findings

According to the results obtained, significant differences between groups were found (p<.05). Control group microtensileee values were found to be significantly higher than all other groups. In the BRIX-3000 group, significantly higher values were obtained compared to the ceramic round and polymer round bur groups (*P*<.05). It was found that the microtensileee values of the ceramic round bur group were significantly higher than the microtensilee values of the polymer round bur group (*P*<.05). It was also found that the steel round bur and Siroinspect groups were significantly higher than the polymer round bur group (*P*<.05).(Table 3)

Table 3. Microtensileee bond strenght values associated with caries removing methods

	0 µm	25 µm	50 µm	75 µm	p
Control (Group 1)	54.91 ± 3.61^{C,a}	59.93 ± 4.57^{B,a}	6.63 ± 4.23^{A,a}	66.47 ± 2.48^{A,a}	<0.001
Steel round bur (Group 2)	33.40 ± 2.42^{D,c}	39.87 ±.3.44^{C,c}	45.94 ± 1.99^{B,c}	54.21 ± 3.08^{A,c}	<0.001
Ceramic round bur (Group 3)	33.23 ± 2.28^{D,c}	3.6 ±1.48^{C,d}	42.85 ± 2.04^{B,d}	54.56 ± 3.60^{A,c}	<0.001
Polymer round bur (Group 4)	27.14 ± 4.95^{D,d}	32.45 ±0.49^{C,e}	38.69 ± 1.00^{B,e}	43,75 ±2.07^{A,d}	<0.001
BRIX-3000 (Group 5)	28.60 ± 4.72^{D,d}	33.54 ±4.47^{C,de}	40.20 ± 3.72^{B,e}	54.41 ±3.48^{A,d}	<0.001
Siroinspect (Group 6)	38.00 ± 4.83^{D,b}	51.18 ± 2.65^{C,b}	57.88 ± 1.86^{B,b}	62.22 ±1.69^{A,b}	<0.001
p	<0.001	<0.001	<0.001	<0.001	

Different lowercase letters indicate a statistically significant difference in columns, and different uppercase letters indicate a statistically significant difference in rows (*P*<.05).

DISCUSSION

The ideal caries removal technique should selectively remove irreversibly destroyed tissue, leaving a potentially remineralizing tissue at the base of the cavity. Although traditional caries removal techniques can irreversibly remove degraded tissue selectively, some intact / affected tissue must be removed to reach the lesion body instrumentally.[12] At the same time, new alternative methods are being developed because the traditional method causes fear, pain, anxiety, and lack of comfort. [13,14]

In in vitro studies investigating the effectiveness of caries removal methods, microhardness measurement is performed to examine the hardness of the dentin tissue remaining in the cavity.[15-17] The decrease in hardness values is directly proportional to the mineral loss. The hardness values of dentin affected by the carious process are reduced compared to healthy dentin tissue.[18,19] In this study, a significant difference was found between the microhardness values at all measurement levels in all groups in which caries removal methods were applied (*P*<.05). Boob et al.[20] obtained significantly higher microhardness values in the excavator group compared to the chemomechanical group in their study where they used the traditional method (excavator) and the chemomechanical method (Papacarie and Carisolv) to remove decayed tissue. Papacarie and Carisolv reported that there was no significant difference between the groups they used. In our study, the microhardness values of the group from which we removed caries with the traditional method were found to be significantly higher than the chemomechanical group at all measurement levels. (*P* <.05)

In their study where they measured microhardness at different levels by removing caries tissue with traditional methods (steel round) and chemomechanical methods (Carisolv, Papacarie), Hamama et al.[21] obtained the lowest microhardness values at the level of 25 µm / chemomechanical method group.

Several previous studies are more reliable in caries detection than FACE traditional visual-tactile examination, the application of a caries detector, or the use of chemo-mechanical methods.[22-25] In this study, the highest values were observed in the Siroinspect group after the control group at all measurement levels in teeth with microhardness test. In addition, we determined the lowest microhardness values in polymer round bur and BRIX-3000 groups in the measurements at the base of the cavity. The microhardness measurements made in the remaining dentin, are parallel to the studies in the literature.[21,26,27] The microhardness values of the intact dentin group were found to be significantly higher than the other groups at all measurement levels. (*P* <.05)

BRIX-3000 acts selectively on infected dentin and not on healthy dentin. Dentin tissue remaining in the cavity after caries removal with BRIX-3000 is called caries-affected dentin. Since the mineral content of the remaining part is lower than healthy dentine, lower microhardness values are obtained.[18,19] In the present study, we think that the significantly lower microhardness values of the polymer round burs and BRIX-3000 groups at all measurement levels compared to the other groups may be due to these reasons.

The microtensileee bond strength values showed a significant difference between the groups in which different caries removal methods were applied (*P* <.05). Aggarwal et al.[28] reported in their study that they used two self-etch and one total-etch adhesive system after removing decay using a steel round bur and chemomechanical method and that the results of the microtensileee bond strength test did not make a significant difference.

Tripathi et al.[29] compared the microtensileee bond strength values after caries removal by conventional and chemomechanical methods and obtained higher values in the chemomechanical group compared to the traditional group. In our study, although we found a significant difference (*P* <.05) between the group in which caries was removed by the chemomechanical method and the polymer round burs and ceramic round burs from traditional methods, we could not detect a difference between the chemomechanical method and the steel round burs group. (*P*> .05)

In their study, Neves et al.[30] used tungsten carbide bur, Cerabur, Cariex, tungsten carbide bur + caries detector, Carisolv, SFC-VIII, and Er-YAG methods, and they found the highest bonding values in the Carisolv group and the lowest bond strength values in the Carisolv group. They also found it in the Er-YAG laser group. They reported that there was no significant difference between the intact dentine and Carisolv group microtensileee bond strength values. According to the results of our study, the second-highest bond strength values were obtained in the chemomechanical method group, and when compared with the control group, a significant difference was detected. (*P* <.05)

The rough dentine surface obtained after caries removal by the chemomechanical method can be considered as the reason for the potential increase in the bonding success of restorative materials due to the presence of micro irregularities that increase the surface area for bonding.[31] The fact that we found the highest microtensileee bond strength values in the BRIX-3000 group after the control group may be due to this reason.

Correa et al. [32] in permanent central teeth, conventional (steel round) and chemomechanical in their studies, in which they measured at certain intervals from 50 µm down to 1500 µm from the cavity floor after removing the decaying using methods (Papacarie, Carisolv), they could not detect a difference between the microhardness values at all measurement levels up to 500 µm level of the steel rod milling cutter and Papacarie groups (*P*>.05); in the Carisolv group, they found the 50 µm level significantly lower than the 500 µm level. (*P*<.05) Reported that the micro-hardness values of all groups significantly decreased in measurements at the level of 1000 and 1500 µm.

Meller et al.[33] reported that after caries removal with a polymer round bur, a more dense smear layer was formed on the remaining dentin surface compared to the dentin surface, which was removed with carbide bur, and that they detected residual caries. Dammaschke et al.[34] and Prabhakar et al.[35] also reported in their in vitro study that they detected a higher rate of residual caries after caries removal with a polymer round mill than steel round milling. The polymer round bur selectively removes caries-infected dentin while leaving caries-affected dentin. Changes may occur in the collagen tissue and mineral density of dentin affected by caries. The present study suggests that achieving lower bond strength values in the polymer round burs group compared to other conventional caries removal methods may be due to these reasons.

A recent study stated that fluorescent aid techniques are a fast, noninvasive method that requires no previous training. These are not affected by other factors, such as plaque and saliva. [36]

The limitations of our study; as a result of the literature review we conducted on sites such as PubMed, Web of Science Core, LISTA (NLM), and Google Scholar, the results obtained could not be compared due to the very low number of studies performed with the Siroinspect device and BRIX-3000. In addition, since it is not possible to apply the 5 different caries removal methods, tests, and surface analyses we used in our study on a single sample, the changes caused by the structural differences of the teeth were ignored.

CONCLUSION

After the control group, the highest bond strength values were determined in the Siroinspect, steel bur, and BRIX-3000 groups. According to the results of the microhardness test, the highest values were obtained in the Siroinspect group after the control group.

According to the results obtained from our study, the Siroinspect device in the category of FACE method can be a reliable alternative to traditional caries removal methods.

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