Case Report
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Ceramic Liner Fracture in Total Hip Arthroplasty: A Case Report

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Background. Ceramic component fracture is a severe complication of primary and revision total hip arthroplasty, leading to multiple revision surgeries.

Case report. This report of rare clinical case of ceramic liner fracture. Fifteen months after a planned left hip replacement, the patient experienced anterior surface pain in the area of the operated joint accompanied by creaking, so the patient went for a consultation. Based on the results of the consultation, the patient was urgently hospitalized and underwent a delayed surgery for revision arthroplasty. Radiologically, there was varus position of the femoral component, dislocation of the bearings. MSCT showed ceramic liner fracture and fragment dislocation. Intraoperatively, the multifragmentary fracture of the liner, significant damage to the head, and retroversion of the acetabular component (retroversion was detected on the preoperative CT scan) were identified. All components of the endoprosthesis and tribologic bearings were replaced with identical ones, total synovectomy was performed, and the wound was cleaned and sanitized.

Conclusion. The presented case report demonstrates the danger of incorrect positioning of the components when using a ceramic bearings. In this case, retroversion of the acetabular component and varus position of the femoral component resulted in a reduced contact area between the head and the liner, which caused the ceramic to fracture. The described observation confirms the need for further in-depth study of the ceramic bearings in order to prevent ceramic component fracture, as it leads to severe complications and significant economic costs.

Keywords: total hip arthroplasty, ceramic bearings, ceramic liner fracture, acetabular component retroversion, revision hip arthroplasty.

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Раскол керамического вкладыша эндопротеза тазобедренного сустава: клинический случай

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Актуальность. Раскол керамических компонентов является тяжелым осложнением первичного и ревизионного тотального эндопротезирования тазобедренного сустава, приводящим к многократным ревизионным операциям.

Описание клинического наблюдения. Представляем редкий клинический случай раскола керамического вкладыша. Через 15 мес. после проведения планового эндопротезирования левого тазобедренного сустава у пациента появились боли по передней поверхности в области оперированного сустава, сопровождающиеся скрипами, вследствие чего пациент обратился за медицинской помощью. По результатам консультации пациент был экстренно госпитализирован и прооперирован в отсроченном порядке в объеме ревизионного эндопротезирования. Рентгенологически отмечались варусное положение бедренного компонента, дислокация пары трения. По данным МСКТ выявлены раскол керамического вкладыша и дислокация фрагментов. Интраоперационно обнаружены мультифрагментарный раскол вкладыша, значительное повреждение головки. На дооперационной КТ была выявлена ретроверсия вертлужного компонента. Выполнены замена всех компонентов эндопротеза и трибологической пары на идентичную, тотальная синовэктомия, рана промыта и санирована.

Заключение. Представленный клинический случай демонстрирует опасность неправильного положения компонентов при использовании керамической пары трения. В приведенном наблюдении ретроверсия вертлужного компонента и варусное положение бедренного компонента привели к уменьшению площади контакта головки и вкладыша, что повлияло на раскол керамики. Описанное наблюдение подтверждает необходимость дальнейшего изучения керамической пары трения с целью профилактики раскола керамических компонентов, так как это приводит к тяжелым осложнениям и значительным экономическим затратам.

Ключевые слова: эндопротезирование тазобедренного сустава, керамическая пара трения, раскол керамического вкладыша, ретроверсия вертлужного компонента, ревизионное эндопротезирование тазобедренного сустава.

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BACKGROUND

Total hip arthroplasty (THA) is currently one of the most frequent surgical interventions in orthopedics. THA has proven as the most effective treatment method in the final stages of hip pathology. One of the main problems of THA is the choice of bearings because the chosen bearings determine the long-term surgical efficiency. At the moment, we have a wide variety of bearings, such as metal-polyethylene (Met-Pe), metal-metal (Met-Met), ceramic-polyethylene (Ce-Pe), ceramic-ceramic (Ce-Ce), and ceramized metal-polyethylene (CerMe-Pe). Met-Pe and Met-Met bearings did not show the best long-term results and manifested themselves as osteolysis due to the presence of friction products thus, in 1970, Boutin et al. proposed Ce-Ce bearings as an alternative to reduce wear and their consequences [1]. The advantages of ceramics are their high wear resistance and optimal biocompatibility, which determines their potential advantages in the long-term when used in young and active patients [2, 3]. However, these bearings were easily fractured due to their fragility, thereby requiring their improvement [4, 5]. The third-generation aluminum ceramics (Forte) are continuously used to date, and the use of fourth-generation aluminum-zirconium composite ceramics has markedly increased (Biolox Delta, CeramTec). The third-generation ceramics showed good serviceability of 95-98% in the long-term follow-up, but their component fragility remained the main problem, as fractures accounted for up to 0.2% of all cases of installed prostheses with ceramics [6]. Biolox Delta ceramics are characterized by a significant increase in tool life and, according to the national registers of England, South Korea, and Norway, the head has become more resistant to fractures, but the destruction rates of the liner remain at the same level, averaging 0.2%, which is 1-2 cases per 1000 [7, 8, 9].

According to the Vreden Center of Traumatology and Orthopedics, in the Russian Federation in 2019, more than 88.5 thousand primary and revision hip arthroplasties were performed, which amounted to 61.3 per 100 thousand population. Concurrently, the share of the Ce-Ce bearings in primary hip arthroplasty is relatively small. The number of cases of its use significantly fluctuated from 2008 to 2020, ranging from 0.5% to 8.2% of the total number of surgeries in different years, but reached 30% in the age group under 30 years [10].

The available Russian literature revealed no reports or descriptions of cases of ceramic liner fracture. The ratio of these complications to survival rate may seem insignificant, but the consequences can be disastrous in the case of improper therapy approach to patients with a fracture. A ceramic liner fracture is often asymptomatic and is not associated with trauma, or it manifests itself only as a creak [11].

This study aimed to describe a rare case in our practice, namely a fracture of a ceramic liner Biolox Delta.

Case report

A 46-year-old patient, with a weight of 115 kg, height of 184 cm, and body mass index of 34, was admitted on February 4, 2022, to the consultative and diagnostic department of Tsivyan Novosibirsk Research Institute of Traumatology and Orthopedics with complaints of noise (crepitus), soreness, and movement limitation in the left HIP, which have been persisting for a week.

In January 2020, the patient was operated on for a road traffic injury, which resulted in a closed fracture of the left proximal femoral metaepiphysis without type A1 displacement. Osteosynthesis was performed with a dynamic hip screw (DHS). In October 2020, primary THA was performed with a proximal fixation endoprosthesis using ceramic bearings due to the avascular necrosis of the left femoral head. The femoral component of Zimmer ML Taper 13.5, an acetabular component of Zimmer Continuum of 60 mm, ceramic head of 36 mm, and ceramic liner of 60/36 mm were implanted in the patient.

On January 27, 2022, a week before visiting the consultative and diagnostic department, the patient stumbled on the left lower limb and felt crepitus in the left hip area. Concurrently, he experienced short-term pain and movement limitation in the prosthetic left hip. The pain decreased during the day spent at rest. However, the symptoms began to increase as the patient became more active within 4 days (from 01/29/2022 to 02/01/2022). Noises (creaking) in the hip during movement appeared in addition to the general symptoms, accompanied by pain (according to the patient, “crepitus during movements”).

An in-depth history taking revealed that the patient noticed the appearance of noises shortly after the left hip arthroplasty before the injury, but did not contact the operating surgeon.

The inguinal and gluteal region examination and palpation revealed no pain or edema. The patient moved using additional support with a limp on his left leg. Relative shortening of 1 cm was observed. Flexion and extension were 0°; abduction was 20°; adduction was 0°; inward rotation was 0°; outward rotation was 0°. The patient felt pain during rotation, abduction, and flexion. Hence, the clinical algorithm recommended by CeramTec for noise interpretation was followed [12].

Sequential X-ray methods of research using plain pelvic radiography in the antero-posterior view revealed a satisfactory inclination of the acetabular component, a varus position of the femoral component of 10°, and a distortion of the endoprosthesis contours in the lower region of the acetabular component and the femoral neck component, which was regarded as a fracture of the ceramic liner or head that make up the bearings. Signs of a previously installed DHS surgical hardware, as well as channels from previously inserted cortical and dynamic screws, were visualized in the cortical area in the upper third of the diaphysis of the left femoral bone after removal in the diaphyseal and subtrochanteric regions (Fig. 1, 2).

Multi-slice computed tomography (MSCT) revealed head decentration. Its correct shape was visualized, which only enabled us to assume its integrity; and a freely lying fragment of a ceramic liner in the neck area of the femoral component was noted. The retroversion was 23° with acetabular component malposition (Fig. 3).

A fracture of the acetabular liner on the left was diagnosed (Fig. 4). A histological examination of the puncture sample was not performed since radiological diagnostic methods were sufficient.

The diagnosis of ceramic liner destruction of the left hip endoprosthesis replaced due to left-sided avascular necrosis of the left femoral head was established based on the obtained data. Following the diagnosis, indications for revision surgery were determined to replace and adjust the positions of all prosthetic components. On the same day, the patient was hospitalized, with strict bed confinement, and his left lower limb was located on a roll under the knee. The patient stayed in a forcedly limited position until surgery.

Fig. 1. Overview X-ray of the hip joints:
on the right — a total hip replacement with a cementless proximal fixation (2019); jn the left — a total hip replacement with a cementless proximal fixation. Dislocation of the elements of the bearing (highlighted in red). The arrows indicate the canals after removal of the screws

Fig. 2. Overview X-ray of the hip joints with full femoral capture. On the left is a 10° varus placement of the femoral component

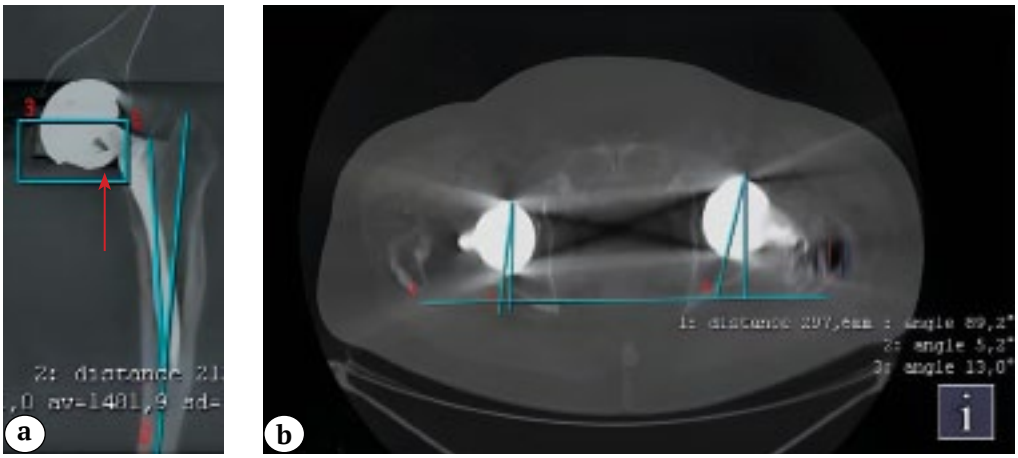

Fig. 3. MSCT:
a — frontal projection: decentration of the femoral component head, its correct shape and a fragment of the ceramic liner in the area of the femoral component neck (arrow) are visualized;
b — axial projection: malposition of the acetabular component on the left — 23° retroversion

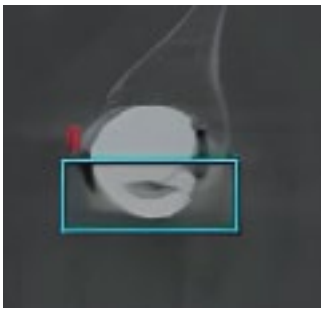

Fig. 4. MSCT, sagittal projection: fracture of the ceramic liner

Revision surgery was performed on February 5, 2022. All actions were performed in the presence of a medical representative of the manufacturer of the fractured component.

The skin, subcutaneous tissue, and fascia were dissected along the previous postoperative scar on the outer surface in the proximal third of the left thigh with the Hardinge approach in the patient's right lateral position under combined anesthesia (spinal and inhalation anesthesia). Cicatrices were mobilized in the greater trochanter area. Approximately 50 ml of odorless hemorrhagic fluid without fibrin was released when the joint capsule was opened. Multifragmentary destruction of the acetabular ceramic liner was visually registered after capsular dissection and femoral component dislocation after the Hohmann retractor installation behind the anterior and posterior columns. All seven visible ceramic liner fragments were removed, and their sizes ranged from 2×3 mm^2 to 20×20 mm^2. Repeating notch-shaped defects were visible along the edges of the preserved large fragments of the liner (marginal zones of the liner). The head was intact. The proximal femur was mobilized, and the endoprosthesis head was removed (Fig. 5).

The femoral component was stable, without signs of bone lysis. The component was extracted by traction with a minor effort using an extractor with preliminary use of osteotomes to mobilize it in the proximal part. Its neutral position was registered when assessing the component torsion. Its installation in the retroversion position was revealed during the acetabular component revision, which corresponded to the preoperative X-ray examination findings. The acetabular component was mobilized using an acetabular gouge and removed. The acetabular contours were preserved, without wall defects. The repeated maximum total synovectomy was performed, followed by the use of the Pulsavac (Zimmer) pulse system to remove ceramic fragments using a water jet. Hemostasis control was performed. A mixed fixation femoral component (Alloclassic) and an acetabular press-fit fixation component (Continuum), as well as Ce-Ce tribological bearings (Biolox Delta), were chosen for the revision replacement of the femoral component. A 62-mm continuum acetabular component due to revision arthroplasty, which was fixed with three screws after impaction, and a 62/36 mm ceramic liner, were installed. The femoral component No. 9 (Alloclassic) was installed, con-

sidering the correction of the varus position of the previous component with installation along the medullary canal axis. The 36 mm + 7 XL ceramic head was chosen for limb length correction. The femoral component was repositioned into the endoprosthesis cup after the head was installed. Their sufficient volume was revealed when testing movements in the left hip joint. Additionally, the surgical wound was sanitized using the Pulsavac system with 1 L of normal saline solution. Finally, the wound was sutured in layers with Vicryl. Staples on the skin and an aseptic dressing were used. The wound healed by primary intention. The patient was discharged on day 10. The plain radiography of the pelvis in the antero-posterior view determined that the acetabular component inclination was 35°, the femoral component was in the correct position when conducting control 3 months postoperatively, and no valgus or varus angulation was noted (Fig. 6). MSCT in the axial projection revealed that the acetabular component was implanted in the anteversion position of 17° (Fig. 7).

Fig. 5. The appearance of the ceramic liner fragments:
a — a large ceramic liner fragment (central) 20×20 mm with signs of metal contact (black);
b — medium (15×6 mm) and small fragments (2×3 mm) with excised surrounding tissues;
c — femoral head with signs of metal contact (black)

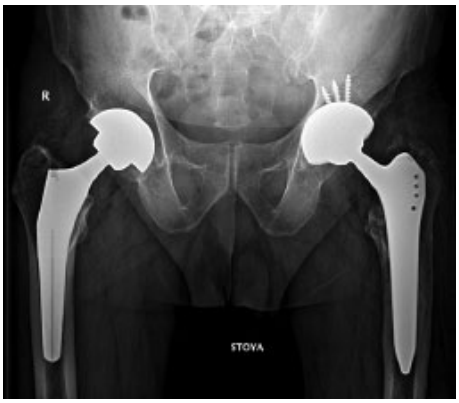

Fig. 6. Anteroposterior X-ray view of the pelvis 3 months after surgery: on the right — a total hip replacement with a cementless proximal fixation (2019); jn the left — a total hip replacement with a cementless proximal fixation

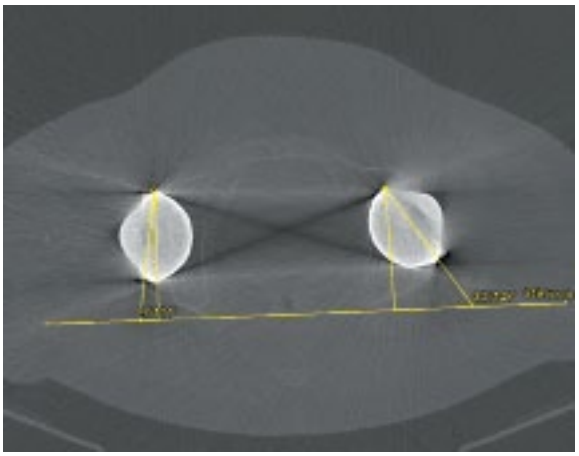

Fig. 7. MSCT of pelvis in axial projection: anteversion of acetabular component 17°

DISCUSSION

Various clinical studies demonstrate a rather high survival rate of endoprostheses with Ce-Ce bearings, namely 97.9–99.6% in the follow-up period of 2–10 years [13, 14, 15, 16, 17], and an insignificant decrease to 95.7% with longer follow-up [18]. Concurrently, only a small share of cases of revision is due to the fracture of ceramic elements, accounting for 0.3%, and <0.2% of them are due to the liner fracture. Untimely and incorrect approaches in this situation can lead to severe consequences for the patient although such complications are rare [19, 20, 21, 22, 23]. Therefore, the main issue is determining the risk factors for ceramic liner destruction. Notably, trauma is rarely the cause of a fracture based on available literature analysis. On the contrary, most of the presented clinical cases do not have a traumatic origin [8, 9, 13, 18, 22, 24, 25, 26]. According to various authors, the incorrect position of the liner and the acetabular component leads to an uneven distribution of the load on the articulating surfaces, which leads to microcrack formation [9, 27, 28], and their accumulation can lead to structural macrodestructions [6]. Malposition of the components can also contribute to the development of impingement of the femoral component neck and the liner edge, or lead to uneven marginal loading of the contralateral side [3, 9, 26, 29].

Some authors revealed the importance of the patient's weight and height [29, 30]. However, Traina et al. revealed that differences in weight and height in the group of patients with a fracture and absence of noise were not significantly different from the comparison group, and concluded that the liner fracture has a multifactorial origin [24]. The same study revealed that the angle of anteversion of the acetabular component was greater in patients with fractures than in those without fractures.

The area with undercoverage has a significant effect. High-strength polyethylene can mitigate the effect of weight redistribution in case of undercoverage of the acetabular component due to its flexibility. The ceramic liner does not cushion the maldistribution of weight due to its hardness [3, 9, 24, 31, 32, 33].

Patient risk factors also remain debatable. There is no approved protocol for working with Ce-Ce bearings, although most orthopedists believe that these bearings can be installed in all young and active patients [3, 6, 34]. The question of the pelvic sagittal balance remains even with the correct placement of the components according to the X-ray data in the antero-posterior view. Additionally, the majority of younger patients are operated on for dysplastic coxarthrosis, that is, with significant anatomical disorders of the joint structure, which entails a shift in the center of rotation, thereby increasing the risk of uneven load on the articulating surfaces [25, 35]. The installation inaccuracy of the same 5°–10° can be significant for the Ce-Ce bearings if Ce-Pe bearings conditionally allow the error of 5°–10° of the angle of inclination or anteversion due to its damping properties [33, 36].

Ceramic debris is bioinert to the body, but studies demonstrated osteolysis due to exposure to ceramic debris. The effect of the influence of a third body should not also be disregarded, because it can significantly reduce the service life of Ce-Ce bearings [6]. Cases of a ceramic bearing fracture due to the third body effect have no exact facts and information, but there are theoretical justifications that the formation of debris between the bearing elements can lead to a violation of the uniform distribution of head pressure on the liner, thereby creating conditions for excessive friction of a certain section and subsequently lead to ceramic destruction [34]. Moreover, there is evidence that coarse debris fragments make scratches and microcracks on the bearing surfaces [28, 37].

Koo et al. revealed that the size of the head in the Ce-Ce bearings plays an important role because bearings with a head of ≤32 mm have a higher risk of component fracture than those with heads of ≥36 mm [38]. Additionally, the head size affects the range of motion in the joint (jumping distance), accordingly, the larger the size, the greater the range of motion [6]. However, an increased head size results in the use of a thinner liner, which directly increases the risk of a fracture and reduces the shelf life of the bearings, or requires an equal increase in the acetabular component diameter. Therefore, installing liners with an anti-luxation tilt with a metal rim or using components with pre-installed liners is recommended to reduce the risk of marginal chipping as the head diameter increases [8, 14, 39].

The surgical approach of revision arthroplasty in case of ceramic destruction is described in the operating procedure from CeramTec [12]. A diagnostic search should be conducted at the first detection of creaking in a Ce-Ce bearing for early ceramic fracture diagnostics. The literature repeatedly indicates that creaking may result from a fracture [40, 41]; however, acoustic phenomena are multifactorial [41, 42], thereby requiring a comprehensive evaluation [12].

Many authors recommend the use of CT for reliable fracture diagnostics. This method is effective in diagnosing fractures without dislocation and malposition of fragments. This is sufficient if fragmentation and dislocation are detected by radiography [18, 38, 43, 44]. Lee et al. proposed the following damage classification [14]:

– marginal splits, which are cases caused by impingement of the neck of the femoral component and the liner from the inner or outer surface, may be indicated by abrasions on the neck surface during revision;

– central fractures (often multifragmentary), where the mechanism is a disproportionate load on the articulating surfaces due to incorrect installation (non-compliance with the parameters of inclination and anteversion, errors during impaction) or loosening of the component.

Histological examination of aspirate from the hip with complaints of creaking may reveal the presence of ceramic fragments. Revision surgery should be performed if a patient complains of creaking accompanied by pain, and ceramic fragments of >5 μm are detected in the synovial fluid [18, 43]. Concurrently, a pre- and intraoperative biopsy of periarticular tissues is recommended for histological diagnostics of the number of macro- and microparticles of debris. The sizes of macroparticles can be 1–22 microns.

The third body effect is the main problem of the consequences of ceramic fracture. Many authors state that approximately 20% of residual debris remains even after total synovectomy and careful treatment of the periarticular space [38, 43, 45]. Accordingly, the choice of bearings during revision is an important component. The Met-Pe bearings are avoided in case of bearing replacement during revision due to ceramic fracture. Complications that occur during short-term follow-up have been repeatedly reported in the literature [38, 41, 45], including a massive metallosis of periprosthetic tissues, induced by residual ceramic debris, which precedes systemic intoxication with cobalt and chromium ions. Patients with a lethal outcome in the medium term after revision with a replacement for Met-Pe bearings were also reported [23]. The best option for revision due to ceramic fracture is the use of similar Ce-Ce bearings, although a hypothesis reported that residual debris can lead to microcracks, and subsequently to repeated fracture [38, 45].

CONCLUSION

The probable cause of the ceramic acetabular liner destruction in our case was the malposition of the acetabular and femoral components. A passive treatment approach after destruction could lead to significant damage to surrounding tissues. A timely revision, according to the CeramTec algorithm, prevented further wear and possible soft tissue disorders. Therefore, introducing a standard protocol for working with these patients in the Russian Federation is advisable because an increased number of primary surgeries with ceramic bearings will undoubtedly increase the number of such complications despite the rarity of ceramic fractures. Clinical cases associated with noises in the hip after hip arthroplasty should be analyzed with great deliberation for early fracture diagnostics. The noise phenomenon, which is divided by the algorithm into frequent noise and intermittent noise, and is not associated with ceramic fractures, requires further study. MSCT is currently considered the best diagnostic method. A histological examination of periprosthetic tissues and punctate can be a significant addition to justify the revision of the bearings in the absence of malposition of the components. Only the Ce-Ce bearings are necessary bearings for the revision of endoprostheses with a ceramic fracture because small particles of ceramics cannot be completely removed by synovectomy, and there will always be a possibility of third body particles entering the friction unit with the development of extremely gross wear.

DISCLAIMERS

Author contribution

Tashtanov B.R. — the collection and processing of data, literature review, writing the draft.

Korytkin A.A. — research conception, data analysis, text editing.

Pavlov V.V. — the treatment of patient, research conception and design, collection and processing of material, data analysis, text editing.

Shubnyakov I.I. — literature review, data analysis, text editing.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

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Ethics approval. Not applicable.

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