Abstract
One benefit of occlusal splint therapy is a reduction in masticatory muscle hyperactivity related to the development of an optimal programmed occlusion. This normalization of muscle activity can reduce the effects of cumulative adverse force on the teeth, periodontium, muscles, and temporomandibular joints. Current literature defines a therapeutic occlusion as multiple, bilateral posterior teeth contact with the mandibular condyles physiologically seated and immediate separation of the posterior teeth by the anterior teeth in all excursive movements. These contacts are usually identified by occlusal marking but research has shown that conventional identification of occlusal contacts with inked silk, paper, or plastic ribbon is not accurate. The rationale and application of computerized digital occlusal analysis to verify a therapeutic occlusion with occlusal splint therapy is presented. The advantages for clinical documentation and validation of research are discussed.

Educational Objectives:
1. Implement the basic and clinical science of occlusion in splint therapy.
2. Utilize the specific requirements for a therapeutic occlusion with splint therapy.
3. Further explore the use of a high technology improvement in splint therapy using computerized digital occlusal analysis.

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Author Disclosure
Dr. Roger Solow discloses that he is a lead visiting faculty and Pankey Scholar at the Pankey Institute.

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The patient can be stabilized with reduced pain to allow for the effect of occlusal correction on the patient’s problem set. For other patients, the optimal treatment may be a noninvasive and more conservative approach with an occlusal splint therapy. There are many advantages to using OS therapy before embarking on more complex procedures. One benefit of occlusal splint therapy is a reduction in muscle activity can reduce the effects of cumulative adverse muscle activity, resulting in pain. Muscle activity can reduce the effects of cumulative adverse muscle activity, resulting in pain. There are advantages to using this therapeutic occlusion as multiple, bilateral posterior teeth contact with the mandibular condyles. The mandibular closure occurs with the condyles physiologically seated in the glenoid fossae. There are 3 requirements for an OS therapeutic occlusion: 1. Multiple, bilateral, and even posterior teeth contact on mandibular closure. 2. Mandibular closure occurs with the condyles physiologically seated in the glenoid fossae. 3. Anterior teeth contact with separate posterior teeth in all mandibular excursions.

Optimal occlusion for occlusal splints

The same occlusal scheme on the OS is used to treat both attritional and hyperactive occlusion providing an optimal force distribution to the uncovered arch. There are 3 requirements for an OS therapeutic occlusion: 1. Multiple, bilateral, and even posterior teeth contact on mandibular closure. 2. Mandibular closure occurs with the condyles physiologically seated in the glenoid fossae. 3. Anterior teeth contact with separate posterior teeth in all mandibular excursions.

Bilateral, even contacts on posterior teeth decrease the force on each individual tooth. An arc of closure interference on a single posterior tooth concentrates all the force of closure on a single tooth. This adverse force stimulates a neurophysiological protective response via the mechanoreceptors of the periodontal ligament to program muscles to avoid the traumatic tooth contact. When the mandibular condyles are seated in the glenoid fossae there is mechanical stability that permits precise rotational movement of the mandible. The inclination of anterior teeth is designed for excursive movements. The inclination of anterior teeth is designed for excursive movements. Dental professionals often fabricate an OS for patients who present with significant attrition of the teeth or myogenic pain in the mandibular elevator muscles. Covering the occlusal surfaces of the teeth with an OS protects those teeth during unconscious nocturnal bruxism. Research has shown that providing a therapeutic OS occlusion decreases the hyperactivity and associated pain of mandibular muscles. Ockerson described the mechanism of muscular hypercontraction on the resultant pain. "There is a circuit of events from teeth to nerves to muscles to teeth. Prolonged posterior teeth contact time leads to prolonged compression time of the periodontal ligaments. Afferent neural impulses from periodontal ligament mechanoreceptors reach the trigeminal motor nucleus and are relayed to the trigeminal spinal tract nucleus which connects to efferent nerves to the mandibular muscles. Conventional tensioning in mandibular muscles with posterior teeth contact results in mandibular muscle contraction and further posterior teeth contact. Prolonged muscle contraction creates lactic acid buildup and toxic ischemia in the muscle fiber, resulting in pain.

Dental professionals typically use the same marking media to adjust the occlusion on an OS as for restorative procedures. However, inked silk, paper, or plastic have been shown to be inaccurate in identifying occlusal interferences. There is no correlation with the size or intensity of the mark and the size or intensity of the actual occlusal contact. The ink mark size correlates to the actual force contact but a pink or red ink mark shows a light mark, a medium contact with a medium to thick mark, and no contact appears as no mark. Thexi text is an inch. The ink mark is an inch. The ink mark is an inch.
Figure 2. 85u thick plastic disposable sensor. The lines contain ink that changes resistance with pressure, generating force data.

The sensor contains lines of pressure sensitive resistive ink oriented in rows and columns. The intersection of these lines forms a sensel. Pressure on the sensel decreases the electrical resistance. The electronics of the instrument scan the sensels at a 495 cycles/second to determine the change in electrical resistance and thus the force. Kerstein has published extensively from 1990 to 2012 on the use of the CDOA to guide occlusal adjustment to treat myofascial pain dysfunction (MPD). He measured real time EMG data showing normalization of masseter and temporalis muscle hyperactivity with the computer guided correction of occlusal interferences. Resolution of chronic pain was long lasting once the source of the pain, adverse force on the posterior teeth, was treated. This was done without the use of drugs, physical therapy, or counseling. Success was predicated on an accurate stone cast if the volatility of the acrylic resin is not tolerated by the patient.

The lateral excursion should have all contact on the canines with no posterior teeth contacts lateral to their point contacts. A lateral excursion contact on a posterior tooth will detract from the smooth guidance desired on the canine as the canine tooth can be slightly lifted off the OS. The canine contact should be a smooth, continuous line and the patient should be able to slide from medial to lateral and lateral to medial on this line without any discernible “hitches” or “jerky movement”. The lateral movement is then repeated with operator assisted force at the angle of the mandible on the non-working side directed medially and superiorly to detect non-working contacts that may occur with mandibular bending during heavy bruxing. An inclination of the canine guidance acrylic ramp will facilitate immediate anterior guidance with posterior teeth disclusion.

After all occlusal markings are perfected, CDOA is then used to analyze the occlusion. The appropriate size sensor and holder are attached to the handle which is connected to the computer. The patient information is entered into the computer file including data such as central incisor width, missing teeth, and spaces to customize the arch form. A multi-bit scan label is chosen and the sensor is centered against the labial aspect of the OS. The patient clenches on their back teeth for several seconds, repeating this 3 times to condition the sensor. This clenching allows for slight sensor cusp incline to cusp incline contacts before occlusal adjustment, so the crimping of the sensor should create a closer adaptation of the sensor to the tooth. However, OS contact is a flat surface against the opposing cusp tip, so the need for conditioning of the sensor is minimal. The sensitivity is adjusted by the operator and computer prompt so that 256 levels of force can be recorded (Fig 4).

It is important to tell the patient to gently “close on their back teeth” to make sure they are in the right position and not closing on the sensor support. When using the sensor on natural teeth, the interdigitation of cusps and fossae helps to orient mandibular closure into a repeatable pattern. Closing on a flat OS with a smooth plastic sensor over it does not provide this orientation and it is possible to inadvertently close on the anterior teeth (Fig 5). If the dental professional observes only anterior teeth contact on the scan, the patient is asked to practice closing on posterior teeth so that their contact is visible on the scan.

Figure 5. Mandibular closure force movie frame after occlusal adjustment is done with the patient in a supine position since patients typically use the OS when sleeping and the condyles seat easier into their physiological position. The occlusion should be checked in both supine and upright positions so that any change in jaw posture does not create an uncomfortable contact. The occlusion should be checked both during patient self closure and CR closure with bimanual guidance for optimal occlusal contacts. The patient should confirm that the bite is “even on both sides” and that “no front teeth hit harder than back teeth”.

Figure 3. Mandibular occlusal split with 20u ribbon marking. Point contacts on posterior teeth indicate only vertical force on the opposing teeth. Continuous lines on anterior teeth indicate the anterior guidance contacts.

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Figure 4. Mandibular closure force movie frame of the occlusion in Figure 3. The apparently even occlusion with ink marking actually shows unbalanced contact force. Note the number and intensity of predominant left side contacts.

A right lateral excursion scan is chosen on the computer and self guided right lateral excursions are performed with the patient instructed to clench and then slide to the right (Fig 7). After immediate disclusion of posterior teeth within 0.4 seconds is confirmed again, the lateral movement is repeated with operator assisted force at the angle of the mandible on the non-working side directed medially and superiorly to detect non-working contacts that may occur on heavy bruxing. The same protocol is repeated for left lateral excursion.

Figure 7. Right lateral excursion showing posterior teeth disclusion and contact forces solely on the canine. Increasing the incline of the canine contact path facilitates immediate posterior teeth disclusion.

Protrusive excursions are then checked, especially on a patient with a pronounced curve of Spee or retained third molars. Posterior teeth are discluded during protrusion by both condyles traversing down the articular eminence, minimizing the chance of protrusive interferences. Posterior teeth must be carefully examined for lateral excursion interferences since only the orbiting condyle traverses down the articular eminence helping to disclude posterior teeth, the rotating condyle does not provide disclusion. This may ex-
plain why working-side interferences contribute the most to masticatory muscle hyperactivity. For this reason, canine guidance is preferable to group function for OS design.

Discussion

Kerstein’s research documented the effect of precise and complete occlusal correction on masticatory elevator muscle activity and the clinical resolution of MDP. One might expect that complete occlusal correction will have a beneficial effect on that patient. However, it is unrealistic to assume that because an OS was delivered it has an excellent or acceptable occlusion. This is important to understand and convey to patients who may decline the recommendation for a proper OS based on their negative experience with a previous OS. In this author’s practice it is very unusual to have a patient bring in an OS that fulfills the requirements for proper fabrication and occlusion. Marking and photographing the patient’s existing OS should be part of the complete examination. Comparing their OS with an example of a proper OS can help the patient understand the specific deficiencies that resulted in a lack of comfort or a poor clinical result.

The requirements of proper OS fabrication with optimal occlusion allow for an individualized clinical decision. Dental professionals rely on research to be objective and directly applicable to clinical decision making. Research that aims to identify the role of occlusal correction in OS therapy should logically test a perfected therapeutic occlusion against a deficient occlusion. It is common for studies to identify the type or general design of OS, but not provide verification of the actual occlusion tested with the CDOA scans. CDOA relative force graphs readily provides this documentation and confirm that the test variable is a therapeutic occlusion. This technology provides a new standard of verification for the validation of dental research. CDOA evaluation of natural occlusion design was shown to be consistent and accurate in the validation of dental research.

CDOA, an EMG recording of masticatory muscles as the patient lightly closes on their posterior teeth. The goal is to discern if one side of the patient’s elevator muscles fires before the other, indicating an earlier contact on that side of the OS. An EMG recording of masticatory and temporals muscle activity on mandibular closure may be a more objective way to do this.

It is common to ask a patient after any procedure involving the bite to comment on how everything feels. Although this may show that the dental professional cares about the patient’s comfort, subjective evaluation by the patient is not consistent or accurate. This is especially true for procedures that patients have not experienced, such as extensive restorative treatment and occlusal equilibration. It is not unusual for them to comment on premature contacts and then mention, “I’m not sure” or “I can’t really tell.” The patient may fear their comments may be incorrect or mislead the dental professional. Highly anxious or critical patients can be stressful to work with when they are given control of determining which side should be adjusted or when the procedure is completed. disequilibrium may result and be expected to correctly make occlusal refinement decisions, this remains the dental professional’s responsibility.

A significant advantage of CDOA is that it gives an objective recording of the timing and relative forces of teeth and restorations. Small or faint ink marks may be significant interferences but not interpreted as such by the dental professional unfamiliar with current research. There show as clear problems on the 2D and 3D scan graphs. CDOA data shows the patient that the goal of an optimal occlusion has been achieved and that this is the correct stopping point. CDOA expertises the outcome of this procedure for the patient and is a thing that is abstract to a visually understandable concept. Patients can readily compare the pre-operative and post-operative scans. It is best to ask for patient feedback after all the details are refined and show as even timing and intensity of contacts on the scans.

For many dental professionals, taking a hands-on course with an OS fabricated for their own mouth is the experience that gives them the understanding of the importance of occlusion for their patients. Additional study and practice is required to master this technology. A participation/hands-on course will provide in depth knowledge of the details that create clinical excellence. The diagnostic and technical skills learned with OS therapy translate into excellence with occlusal equilibration and comprehensive restoration.

Conclusion

OS therapy is an important treatment modality since there are many patients with attrition and myogenous orofacial pain that can benefit from protection and pain relief. Verifying a therapeutic occlusion is prerequisite to determining the effect of occlusal correction on the patient. Dental professionals require occlusal adjustment indicators for OS fabrication and fabrication that lead to predictable treatment results. CDOA dramatically improves the dental professional’s ability to diagnose, create, and document an optimal occlusion, a critical aspect of OS therapy. Objective data of occlusal contact forces in 3D format show the patient and dental professional where the problem is and the results of treatment or occlusal adjustment. It uses specific methods of occlusal equilibration to determine if occlusal adjustment is required.

References

1. Occlusal splints are commonly used to help patients with attrition of teeth and myogenous pain in the mandibular or maxillary muscles. Which statement is true?
   a. The jaw posture slightly changes when the patient sits up or lays back.
   b. Occlusal splints are sometimes used by dentists to guide occlusal correction for myofascial pain patients.
   c. Occlusal splints are often not effective because the splint closes "unevenly on both sides".
   d. Both the central and lateral incisors should touch the splint at the same time as the posterior teeth.

2. Which one is not a requirement of occlusal splint therapeutic occlusion?
   a. The jaw posture slightly changes when the patient sits up or lays back.
   b. Occlusal splints are sometimes used by dentists to guide occlusal correction for myofascial pain patients.
   c. Occlusal splints are often not effective because the splint closes "unevenly on both sides".
   d. Both the central and lateral incisors should touch the splint at the same time as the posterior teeth.

3. Anterior teeth are the best choice to guide the mandible in excursions because:
   a. They form a pivot or fulcrum in a Class 3 lever system.
   b. They are inclined and elevate decrease muscle activity when back teeth separate.
   c. The long teeth are thicker with better leverage than posterior teeth.
   d. They are the least sensitive teeth and tolerate the occlusal load the best.

4. If the condyle is not properly seated in the glenoid fossa, it is braced in a protruded position on the slope of the articular eminence by which muscle?
   a. Inferior lateral pterygoid muscle.
   b. Anterior temporalis muscle.
   c. Masseter muscle.
   d. Medial pterygoid muscle.

5. Soft occlusal splints are sometimes used by dentists. Which statement is true?
   a. Soft splints are laboratory made compression splints which allow more teeth to touch and bear the load evenly.
   b. Current soft splints are resistant to occlusal wear.
   c. Soft splints are easy to keep clean.
   d. Always slide in all directions as if you were biting the sensor holder.

6. What is the name of an occlusal splint which is more effective than the conventional inked ribbon splint?
   a. T-Scan sensors for recording bite forces in denture patients.
   b. Digital occlusal analysis to guide occlusal correction for myofascial pain patients.
   c. Digital occlusal analysis records a force movie and each frame can be analyzed.
   d. Occlusal splints must be comfortable to the patient for them to be used consistently over the long term. Which statement is not true?

7. Computerized digital occlusal analysis can be used in a variety of clinical situations. Which one is not true?
   a. Partial dentures and complete dentures are candidates for use.
   b. It is important for operators to first perform occlusal analysis before initiating the splint fabrication.
   c. The analysis of occlusal loads can be used to reline a complete denture.
   d. Always slide in all directions as if you were biting the sensor holder.

8. Kerstein’s research used computerized digital occlusal analysis to guide occlusal correction for myofascial pain patients. Which statement is true?
   a. Kerstein’s research used computerized digital occlusal analysis to guide occlusal correction for myofascial pain patients.
   b. Kerstein’s research used computerized digital occlusal analysis to guide occlusal correction for myofascial pain patients.
   c. Kerstein’s research used computerized digital occlusal analysis to guide occlusal correction for myofascial pain patients.
   d. Always slide in all directions as if you were biting the sensor holder.

9. Many dentists work with their patients on the occlusal splint fabricating process. Which statement is not true?
   a. The jaw posture slightly changes when the patient sits up or lays back.
   b. Occlusal splints are sometimes used by dentists to guide occlusal correction for myofascial pain patients.
   c. Occlusal splints are often not effective because the splint closes "unevenly on both sides".
   d. Both the central and lateral incisors should touch the splint at the same time as the posterior teeth.

10. Occlusal splints must be comfortable to the patient for them to be used consistently over the long term. Which statement is not true?
    a. There are advantages to using computerized digital occlusal analysis compared to conventional inked ribbons.
    b. Computerized digital occlusal analysis is a new technology procedure invented in 2018 by Masone.
    c. Digital occlusal splints are easy to keep clean.
    d. Occlusal splints must be comfortable to the patient for them to be used consistently over the long term.

11. Computerized digital occlusal analysis can be used in a variety of clinical situations. Which one is not true?
    a. Partial dentures and complete dentures are candidates for use.
    b. It is important for operators to first perform occlusal analysis before initiating the splint fabrication.
    c. The analysis of occlusal loads can be used to reline a complete denture.
    d. Always slide in all directions as if you were biting the sensor holder.

12. Computerized digital occlusal analysis can be combined with occlusal splint therapy to verify that a therapeutic occlusion is attained. Which instruction should not be given to the patient?
    a. Always bite gently on the back teeth to avoid biting the sensor holder.
    b. Always bite gently on the back teeth before chewing firmly.
    c. Always bite gently on the back teeth before chewing firmly.
    d. Always bite gently on the back teeth before chewing firmly.

13. Posterior teeth are separated during mandibular excursions by the anterior teeth and the condyles traversing down the articular eminence. Which statement is true?
    a. In protrusion both condyles traverse down the slope of the articular eminence.
    b. In lateral excursion the condyle traverses down the articular eminence.
    c. In left lateral excursion the orbiting condyle is separated back to back.
    d. In right lateral excursion the non-orbiting condyle is separated back to back.

14. Computerized digital occlusal analysis can be used to guide occlusal correction for myofascial pain patients. Which statement is true?
    a. Kerstein’s research used computerized digital occlusal analysis to guide occlusal correction for myofascial pain patients.
    b. Kerstein’s research used computerized digital occlusal analysis to guide occlusal correction for myofascial pain patients.
    c. Kerstein’s research used computerized digital occlusal analysis to guide occlusal correction for myofascial pain patients.
    d. Always slide in all directions as if you were biting the sensor holder.

15. Kerstein’s research used computerized digital occlusal analysis to guide occlusal correction for myofascial pain patients. Which statement is true?
    a. Kerstein’s research used computerized digital occlusal analysis to guide occlusal correction for myofascial pain patients.
    b. Kerstein’s research used computerized digital occlusal analysis to guide occlusal correction for myofascial pain patients.
    c. Kerstein’s research used computerized digital occlusal analysis to guide occlusal correction for myofascial pain patients.
    d. Always slide in all directions as if you were biting the sensor holder.

16. Many dentists work with their patients lying down, some have them sit up. Which statement is true?
    a. The jaw posture slightly changes when the patient sits up or lays back.
    b. Occlusal splints are sometimes used by dentists to guide occlusal correction for myofascial pain patients.
    c. Occlusal splints are often not effective because the splint closes "unevenly on both sides".
    d. Always slide in all directions as if you were biting the sensor holder.

17. Kerstein’s research used computerized digital occlusal analysis to guide occlusal correction for myofascial pain patients. Which statement is true?
    a. Kerstein’s research used computerized digital occlusal analysis to guide occlusal correction for myofascial pain patients.
    b. Kerstein’s research used computerized digital occlusal analysis to guide occlusal correction for myofascial pain patients.
    c. Kerstein’s research used computerized digital occlusal analysis to guide occlusal correction for myofascial pain patients.
    d. Always slide in all directions as if you were biting the sensor holder.
21. Which is not true about a splint?
   a. Force is placed on the chin during lateral excursion.
   b. The teeth with the best periodontal support are used in the working side.
   c. The splint can be relined either intraorally or on the anatomic stone cast.
   d. Soft splints are more comfortable to the bite than hard splints.

22. Retention is defined as resistance to vertical dislodgement. Which statement is true?
   a. Soft splints are more retentive than hard splints since they extend into the undercut.
   b. Soft splints move slightly vertically allowing more teeth to touch with a more even occlusion.
   c. A soft splint is not retentive as a hard splint.
   d. A hard splint is retentive since it extends into the undercut of the buccal contour of the teeth.

23. Soft and hard splints affect the masticatory muscle electromyographic activity. Which statement is true?
   a. Soft splints increase masticatory muscle activity.
   b. Hard splints increase masticatory muscle activity.
   c. Soft splints achieve the optimal therapeutic masticatory muscle activity.
   d. Soft splints achieved the optimal therapeutic masticatory muscle activity.

24. The anterior guidance on occlusal splints is designed to separate posterior teeth during mandibular excursions. Which of these statements is not true?
   a. Anterior tooth contact should be customized for each patient.
   b. The teeth with the best periodontal support are used in the canines.
   c. Anterior guidance contacts mask a continuous line.
   d. Distributing force over several teeth can minimize the force on each tooth.

25. Relining a splint will result in a stable fit with no mobility. Which of these statements is not true?
   a. Research on occlusal correction should test a perfect therapeutic occlusion against a deficient occlusion.
   b. Most-study verify the therapeutic occlusion used in the study.
   c. Computerized digital occlusal analysis can provide documentation of the actual occlusion obtained.
   d. The same requirements of splint fabrication for clinical use apply to dental research.

26. Occlusal splint therapy is important treatment since there are many patients with pain from tooth movement and pain relief. Which of the following is not true?
   a. A verified therapeutic occlusion must be done to assess the effect of occlusal correction on that patient.
   b. Computerized digital occlusal analysis dramatically improves the dentist’s ability to diagnose and treat with an occlusal occlusion.
   c. Computerized digital occlusal analysis is an experimental research tool that is not typically used for patient care.
   d. Objective data shows the patient and dentist were satisfied and the results of treatment.

27. Evaluation of the patient’s splint is part of the comprehensive examination. Which of these statements is not true?
   a. You should mark and photograph the existing splint.
   b. You can compare the existing splint with an example of a perfected splint.
   c. You cannot assume that a splint will have a predictable result without a therapeutic occlusion.
   d. If the patient could not tolerate a splint it is unreasonable to recommend another one.

28. It is critical to deliver a splint with an optimum occlusion that is comfortable for the patient. Which of these statements is true?
   a. Patients can sense about 15° of occlusal change so they should judge the bite.
   b. Patient evaluation of the occlusion is subjective and not accurate.
   c. Splint adjustment is best controlled by the patient.
   d. Soft splints are more comfortable to the bite than hard splints.

29. Dentists rely on clinical research to be objective and relevant to daily practice. Which of these statements is not true?
   a. Verifying a therapeutic occlusion must be done in a stable fit with no mobility.
   b. Patient evaluation of the occlusion is subjective and not accurate.
   c. Computerized digital occlusal analysis can be used in the study.
   d. Research on occlusal correction should test a perfect therapeutic occlusion against a deficient occlusion.

Educational Objectives
1. Implement the basic and clinical science of occlusion in splint therapy.
2. Utilize the specific requirements for an therapeutic occlusion with splint therapy.
3. Further explore the use of high technology improvement in splint therapy using computerized digital occlusal analysis.

Course Evaluation
1. Where did the individual course originate from?
   Objective #1: Yes No
   Objective #2: Yes No

2. To what extent were the course objectives accomplished overall?
   5 4 3 2 1
   1. 2. 3. 4. 5.

3. Please rate the general mastery of the course objectives.
   5 4 3 2 1
   5 4 3 2 1

4. How would you rate the objectives and educational methods?
   5 4 3 2 1
   5 4 3 2 1

5. How do you rate the author’s group input of the course?
   5 4 3 2 1
   5 4 3 2 1

6. Please rate the instructor’s effectiveness.
   5 4 3 2 1
   5 4 3 2 1

7. Was the overall administration of the course effective?
   5 4 3 2 1
   5 4 3 2 1

8. Please rate the format and clinical applicability of this course.
   5 4 3 2 1
   5 4 3 2 1

9. Please rate the format and the supplemental webliography.
   5 4 3 2 1
   5 4 3 2 1

10. Do you feel that the instructors were competent?
    Yes No

11. Would you participate in a similar program on a different topic?
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