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REVIEW ARTICLE

Fixation Methods Used in Sagittal Split Ramus Osteotomy

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ABSTRACT

The sagittal split ramus osteotomy (SSRO) is a technique frequently used in orthognathic surgery for the treatment of congenital or acquired mandibular irregularities. Congenital or acquired deformities of the mandible, such as hypoplasia, hyperplasia, and asymmetry, can be corrected with this method. The SSRO procedure creates a broad bone contact surface in the mandible, supporting both post-operative stability and the early healing process. Additionally, this technique prepares a suitable foundation for the application of various fixation methods. The correct fixation of the segments after osteotomy directly affects the success of the procedure. Ensuring immobility between the bone fragments is of critical importance to the success of the surgery. Among the fixation materials and techniques used after SSRO are wire osteosynthesis, intermaxillary fixation, bicortical screw systems, mini plate-screw systems, hybrid systems using bicortical screws and plates, and resorbable mini plate-screw systems. An ideal fixation system should promote rapid bone healing, the commencement of early mandibular function post-operatively, and a reduction in the amount of relapse. However, despite many studies on this topic, an universally accepted ideal fixation method has yet to be determined. In our review, various fixation types and methods used for the frequently applied SSRO method in orthognathic surgery have been examined in detail. Information on the advantages, disadvantages, and effectiveness in clinical application of these techniques has been provided. The selection of the correct fixation method, which plays a critical role in the success of SSRO, is believed to directly impact both patient outcomes and the healing process. In this context, our review aims to provide clinicians with information and guidance in determining the most suitable fixation method for potential clinical scenarios they may encounter.

Keywords: fixation, stabilization, sagittal split ramus osteotomy

SSRO is a mandibular orthognathic surgical procedure that allows the correction of dentofacial deformities. The first mandibular osteotomy surgery was performed in 1849 by Hullihen. Since then, many different mandibular osteotomy methods have been developed; however, the sagittal osteotomy design of the ramus described by Trauner and Obwegeser in 1955 has become the most popular method. This osteotomy design has undergone various modifications over time. The original osteotomy design by Trauner and Obwegeser has evolved over time with various improvements by Dal Pont, Hunsuck, and Epker to its present form.[1,2]

Today, SSRO is the most frequently used method among mandibular orthognathic surgical techniques. Various movements can be achieved in the mandible with SSRO. The main indications for this method are:

1. Cases of mandibular retrognathia where the mandible needs to be moved forward.
2. Cases of mandibular prognathia where the mandible needs to be moved backward.
3. Cases of mandibular asymmetry.

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In addition to these indications, there are some contraindications:

1. Situations where the height of the ramus is significantly insufficient.
2. Cases where the mediolateral dimension of the ramus is thin.
3. Patients with advanced ramus hypoplasia.[1,3]

While this technique offers a series of advantages, it also harbors potential disadvantages and risks. A comprehensive evaluation of SSRO will help determine the potential benefits and complications of using this method.

Advantages of SSRO include:

1. Allows movement of the distal segment in all three planes.
2. The post-surgical healing process occurs rapidly.
3. Enables positioning of the segments in the desired position during the operation.
4. Causes minimal changes in the muscles. As a result, the risk of relapse is low.
5. Allows for the preservation of the natural position of the temporomandibular joint.
6. The operation duration is short and the complication rate is low.[4,5]

Disadvantages of SSRO include:

1. There is a risk of temporary or permanent nerve damage in the inferior alveolar nerve.
2. Malocclusion can occur as a result of incorrect condyle positioning.
3. Unwanted fractures and separations can occur during the operation.[6,7]

The SSRO procedure is a technique that allows for the repositioning of the mandible and is performed with bone cuts in the sagittal plane. This procedure is done with the aim of bringing the mandible to a more aesthetically and functionally ideal position. However, this procedure requires the repositioning of the mandible in a precise and accurate manner while preserving anatomical and neural structures. For this reason, high surgical skill and detailed planning are necessary. It is essential for surgeons to conduct a comprehensive evaluation to determine the most appropriate treatment method for each patient.[3]

WHAT IS FIXATION?

During orthognathic surgery, the immobility of the created segments is ensured by fixation methods until the healing process is completed in the post-operative period. Ensuring the fixation of the segments in the correct anatomical position is extremely important.[1,8]

After SSRO fixation, rotation can occur in the segments. The proximal segment undergoes counterclockwise rotation because it is pulled anterior-superiorly by the masseter and temporal muscle fibers. The distal segment undergoes counterclockwise rotation as well, due to being pulled posterior-inferiorly by the mylohyoid, geniohyoid, genioglossus, and suprahyoid muscles. As a result of these rotation movements, relapse occurs. Relapse is a multifactorial outcome. Relapse occurring within the first 6 months post-operation is termed early-period relapse, while that occurring after 6 months is termed late-period relapse. Among the causes of relapse after SSRO, the chosen fixation technique, insufficient stabilization of fragments, and muscle and soft tissue tensions play a significant role. Currently, it is known that relapse occurs and ramus height decreases due to the inability to position the condyle ideally.8,9 It is reported that the highest rate of relapse in orthognathic surgery occurs in the 2nd postoperative month. Therefore, the impact of different fixation methods on skeletal stability has pushed many clinicians and researchers to search for the ideal fixation system.[1,8]

An ideal fixation system should allow the patient to move their jaw in the early postoperative period, maintain facial ratios and occlusion, be easy to apply, be cost-effective, be compatible with facial tissues, and minimize the risk of infection. In addition, it should provide maximum resistance to masticatory forces and induce minimal stress in surrounding tissues. However, to this day, there is no fixation system that fully conforms to these criteria. When selecting a fixation system, a choice should be made taking into consideration the patient's general health, age, gender, bone quality, treatment objectives, anatomical structure, desired level of stability, postoperative relapse risk, and the surgeon's experience and preferences.[1,3]

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FIXATION RIGIDITY

Non-Rigid Fixation

It's a type of fixation that is not rigid enough to completely prevent movement between fragments while the skeletal structure is actively in use. This movement constitutes the primary difference between rigid and non-rigid fixation.

Wire fixation is an example of non-rigid fixation applied in mandibular fractures. This type of fixation can provide stability by preventing the expansion of the gap, but it cannot neutralize torsional and shearing forces. Additional fixation methods, such as maxillomandibular fixation (MMF), are needed to neutralize such forces.

As a result of the application of non-rigid fixation, there is slight mobility between fragments, hence healing occurs as secondary bone healing. In secondary bone healing, a tissue called periosteal callus forms. This process involves tissue differentiation that goes through various stages, including resorption and fibrous healing around the bone fragment.[1,10]

Semi-Rigid Fixation

It's a type of fixation that is strong enough to allow active movement of the skeletal structure during the healing period but not stable enough to prevent movement between fragments. Such fixations are referred to as functional stabilization. Although they might not provide enough stability for direct bone healing, they offer a level of stability that permits functional movement. The application of a single mini-plate in fractures of the mandibular angle or mandibular body can serve as an example of semi-rigid fixation. Even though there's movement between fragments in this type of fixation, clinical outcomes have been observed to be extremely successful. In an area where semi-rigid fixation is applied, secondary bone healing occurs.[1,10]

Rigid Fixation

Rigid fixation can be defined as a type of fixation that allows active use of the skeletal structure, is strong enough to prevent the movement of mobile fragments, and is applied directly to the bones. This definition encompasses the anatomically correct positioning of bone fragments through surgical intervention and their stable fixation. Examples of rigid fixation applications in the mandible include the combined use of plates and screws, and the application of 2 lag screws.

During rigid fixation, there is no callus formation during bone healing. The bone healing that occurs as a result of rigid fixation is referred to as primary (direct) bone healing. For primary bone healing to commence, perfect immobilization between bone fragments must be ensured, and there should be minimal gap between the fragments.[1,10]

FIXATION METHODS USED AFTER SSRO:

1. Rigid Intermaxillary Fixation
2. Osteosuture (Fixation with wire)
3. Osteosynthesis (Bicortical screw, use of Plates and Monocortical screws, Hybrid Systems)
4. Resorbable Systems

Rigid Intermaxillary Fixation

Rigid intermaxillary fixation is currently used in conjunction with wire fixation. In the past, although rigid intermaxillary fixation was used after SSRO surgeries, a relapse rate of 90% was observed. The bone segments were not stable after fixation, leading to movements in the proximal and distal segments exposed to muscle and soft tissue tension during the postoperative period. As a result, adequate stabilization could not be achieved. Moreover, rigid intermaxillary fixation, which is done by taking force from natural teeth, led to the extrusion of the teeth and encountered relapse. The inability to achieve sufficient stabilization and the resulting relapse suggested that rigid intermaxillary fixation was not adequate for fixation after SSRO, pushing surgeons to seek new methods.[11,12]

Osteosuture (Wire Fixation)

The initial wire fixation was done to support maxillomandibular fixation by passing the wire through the priform rim and circummandibularly binding it to the premolar and molar teeth. Subsequently, wire fixation applications have been performed in various regions and configurations. Wire fixation has generally been used in surgical operations where the mandible is moved backward.[1,10]

Osteosynthesis (Bicortical screw, Use of plates and monocortical screws, Hybrid Systems)

The inability of rigid intermaxillary fixation and wire fixation to provide adequate stability has pushed surgeons to seek more stable, rigid, and reliable fixation systems. In 1974, Spiessel

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described a fixation method using lag screws to accelerate healing and enhance stability. In 1978, the use of positional screws began due to concerns that lag screws generated torque in the condylar segment and caused damage to the inferior alveolar nerve. From the 1980s onwards, the use of monocortical screw and plate fixation has started.[11,13,14]

Screws

Screws used in orthognathic surgery are employed for the fixation of plates to the bone or for keeping bone fragments together. Monocortical screws and bicortical screws are frequently used in orthognathic surgery. Screws are typically named based on the external diameter of the thread. The diameter of screws used in orthognathic surgery usually ranges between 1.0 mm and 2.7 mm. In the event of fixation failure, there are emergency screws available that are larger than the screw previously used. Based on their placement into the bone, screws are classified as self-drilling and self-tapping.[14] (Figure 1)

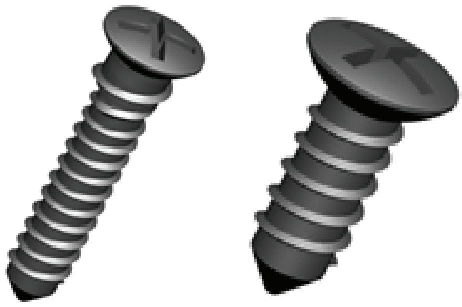

Figure 1. Bicortical Screw Monocortical Screw

Bicortical Screws

In orthognathic surgery, the application of bicortical screws initially began with the use of lag screws. Lag screws work on the principle of pulling bone fragments towards each other, hence they are also referred to as pull screws. Lag screws have threads only at their distal end, and when fixation is applied, they cause compression in both proximal and distal segments. The use of lag screws ensures rigid fixation of bone fragments and, due to the high level of bone contact, they also initiate primary bone healing. For lag screws to be used, both bone segments need to have a thick cortical structure. For the screw to fulfill its lag function, it needs to transition from a wider groove to a narrower one, resulting in pressure between bone segments upon fixation. Among the advantages of lag screws are that they provide an extremely rigid fixation, have a relatively low cost, and require minimal equipment.[1,15]

However, there are also several disadvantages to using lag screws. In cases where there is a gap between bone segments, displacement can occur in both the proximal and distal segments as a result of lag screw application. Since lag screws operate on the principle of compression, damage can occur in the inferior alveolar nerve that lies between bone segments.[3,16] Moreover, studies have shown that the use of lag screws in mandibular advancement can lead to temporomandibular joint dysfunction and condylar displacement due to their compressive effects.[11]

Figure2. Bicortical screw application after SSRO surgery

To avoid the drawbacks of lag screws, the use of positional screws came into play in subsequent years. Positional screws anchor to both the distal and proximal segments. The screw hole is prepared with an equal diameter in both segments. Unlike lag screws, positional screws do not cause compression in the distal and proximal segments during fixation. Since no

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compression occurs in positional screw fixation, no torque is generated in the segments or condyle. Additionally, it has been observed that the risk of nerve damage due to positional screw fixation is significantly reduced compared to lag screw fixation. However, in positional screw applications, if the segments are not aligned properly, they can drift apart. Because there's no pulling force resulting from fixation, it's extremely difficult to determine if the screw has anchored to the medial segment. Even if the screw doesn't attach to the medial segment, it can still lodge in the lateral cortex.[3,17] (Figure 2)

After SSRO, 2 or 3 bicortical screws are typically used for fixation. Bicortical screws can be placed in linear, reverse L, and L positions.(Figure3,4)

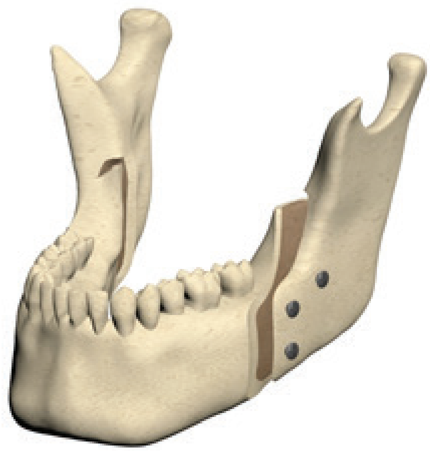

Figure 3. Application of 3 bicortical screws in inverted L position after SSRO

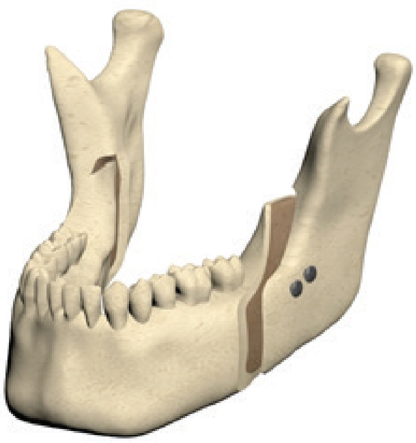

Figure 4. Application of 2 bicortical screws in linear position after SSRO

Plates

Due to anatomical restrictions, the challenge of applying bicortical screws over time has led to the use of plates in orthognathic surgery. The plates used in orthognathic surgery differ in terms of size, shape, and purpose of use. In craniofacial regions, plates are used in flat, X, Y, double Y, H, and L configurations. The thickness of these plates typically varies between 0.5 mm and 0.9 mm. Plates used in mandibular orthognathic surgery are designed as 1-1.5 mm thick microplates and 2.0 mm thick mini plates.(Figure 5) Plates used in mandibular orthognathic surgery provide functionally stable fixation that allows bone compatibility and bone healing.[3,14]

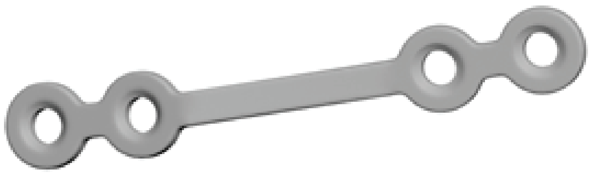

Figure 5. 4-hole conventional miniplate

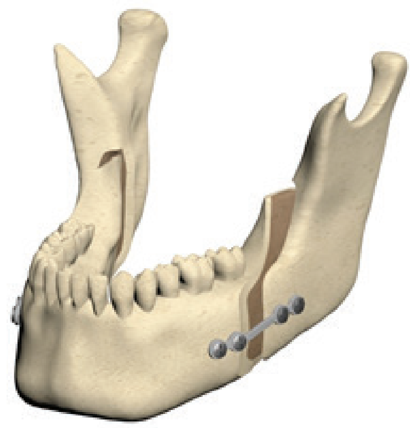

Figure 6. 4-hole conventional miniplate application after SSRO surgery

In 1973, Michelet and colleagues first recommended mini plate and monocortical screw fixation after SSRO.[18]

Mini plates are a routinely used fixation system in mandibular orthognathic surgery. Mini plates used in mandibular orthognathic surgery are available as 2-hole, 3-hole, 4-hole, 6-hole, and 8-hole.[10] (Figure 6) They can be categorized

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as conventional mini plates and locked mini plates. In conventional mini plate systems, the plate is pressed towards the bone as a result of the fixation with a monocortical screw. Primary stability is provided by this pressure. The plates must be positioned correctly onto the bone. Incorrect positioning of plates results in a loss of stability. Due to their design, stability loss is more frequent in conventional plates compared to locked plate systems. In locked plate systems, screws hold onto both the plate and the bone. In this type of fixation, the plate does not exert pressure on the bone. Therefore, bone nutrition is higher and the likelihood of screw loosening is lower.[14]

The advantages of using mini plates after SSRO include the ability to place them intraorally, the ability to adjust the position of the distal and proximal segment in the early period, the low risk of damage to the inferior alveolar nerve, the ability to remove the plate and monocortical screw under local anesthesia, and causing minimal displacement in the condyle. On the other hand, disadvantages include plates showing less stability compared to bicortical screws, susceptibility to infection, inability to withstand chewing forces leading to breakage, and thermal sensitivity.[1]

Hybrid Systems

Hybrid fixation is a fixation method that involves the combined use of plates, monocortical screws, and bicortical screws. In this method, the aim is to increase the existing stability by utilizing the advantages of plates and bicortical screws and to distribute the resulting stresses homogeneously. The hybrid fixation technique was first introduced by Schwartz and Relle in 1996. In their study, the researchers suggested stabilizing the segments with a mini plate after bringing the segments to the correct anatomical position and then providing rigid fixation with bicortical screws. According to the results of the study, they reported that hybrid fixation increased stability and reduced the risk of postoperative recurrence.[19] (Figure 7)

Resorbable Systems

In the face of infections, inflammations, and toxic reactions seen in fixation systems made of titanium and stainless steel, the use of resorbable materials in orthognathic surgery has come to the fore. These materials are derived from Polyglycolic Acid (PGA) and Poly-L Lactic Acid (PLLA). It was believed that plates and screws made of these materials could successfully stabilize the segments 6-8 weeks after surgery. Resorbable materials dissolve into water and carbon dioxide, eliminating the need for a second surgery to remove the materials. In addition, there are disadvantages of resorbable materials such as being palpable from tissues due to their thickness, high cost, and thermal sensitivity.[4,20,21]

Figure 7. Hybrid fixation application after SSRO surgery

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DISCUSSION

Since its description by SSRO, Trauner, and Obwegeser in 1955, the SSRO technique has become a significant method in correcting mandibular deformities. This technique is widely preferred among surgeons for correcting various mandibular deformities such as congenital or acquired hypoplasia, hyperplasia, and asymmetry. Despite its advantages like high healing potential and ease of use, ongoing debates persist regarding the choice of fixation method. Stability plays a critical role in the success of repositioning mandibular segments after osteotomy. Despite extensive research on the ideal fixation technique, a general consensus has not yet been reached. Traditionally, fixed orthodontic appliances, modified splints, and occlusal splints have been used, but the development of rigid internal fixation systems like bicortical screws and miniplates has surpassed these practices.[1,3]

In 1974, the rigid internal fixation method described by Spiessl and Tschopp improved the reliability and stability of SSRO. During this period, various fixation techniques were used, such as screws placed in a reverse L shape and linearly on the upper border to maintain the new skeletal position. However, complications associated with bicortical screw usage have led surgeons to explore alternative techniques. Since the 1980s, new fixation systems like miniplates and monocortical screws have been introduced to avoid these complications.[13,22]

In a study conducted by Dolce et al. in which they compared wire fixation and bicortical screw fixation in patients undergoing mandibular advancement with SSRO, it was reported that wire fixation resulted in a 42% recurrence rate after 5 years. Researchers believed that wire fixation did not provide adequate stability after mandibular advancement.[23]

Watzke et al. compared bicortical screw and wire fixation for stability in patients undergoing mandibular advancement with SSRO at postoperative 6 weeks and 1 year. The study found that bicortical screw fixation was more stable, with a 15% recurrence rate associated with wire fixation.[11]

In a study by Maurer et al. in 2003, they compared the placement of three bicortical screws in a reverse L position with conventional miniplate fixation using finite element analysis after SSRO. The study concluded that bicortical screw fixation provided more stable results against chewing forces.[24]

Peira Filho et al. compared three different fixation methods after SSRO in a 2013 study. They applied force to polyurethane mandible models until a 10 mm displacement occurred. The study concluded that the placement of three bicortical screws in a reverse L position was more stable than a 4-hole conventional miniplate and a sagittal split sliding plate.[25]

In a study conducted by Sindel and colleagues in 2014, they compared the effects of bicortical screw configurations on stability after SSRO. According to the results of the study, it was reported that the configuration with 3 bicortical screws placed in a reverse L position was the most stable, followed by 3 bicortical screws placed in an L position and 3 bicortical screws placed linearly.[26]

The use of bicortical screws has limitations due to the need for extraoral access, the risk of nerve damage, the possibility of bone resorption caused by stress, and the potential to increase temporomandibular joint disorders. However, in vitro and clinical studies have reported no statistically significant difference in postoperative changes between bicortical screw and miniplate fixation techniques.

In a study by Olivera et al. in 2012, they compared the biomechanical results of three fixation methods (three bicortical screws in a reverse L position, hybrid fixation, and two 4-hole conventional miniplates) in a sheep mandibular model undergoing 5 mm mandibular advancement with SSRO. The study found that all three fixation systems provided similar biomechanical results until a bone fracture occurred in the second molar region.[13]

Furthermore, a prospective multicenter study by Borstlap et al. reported that miniplate fixation after SSRO provided sufficient stability and high patient satisfaction, making it a reliable method.[27]

In the future, it has been suggested that the use of bicortical screws in addition to the miniplate system may have a positive effect on stability, and the use of hybrid fixation is recommended to take advantage of the benefits of both systems. With hybrid fixation, the goal is to achieve more effective stability in orthognathic surgery by combining the high stability provided by bicortical screw fixation with the minimal invasiveness and ease of use of miniplates.[19]

In a study by Oğuz et al. in 2015, they compared six different fixation methods in mandible models undergoing 5 mm advancement after SSRO. Hybrid fixation was used in one group, while various types of plate fixation were used in five groups. The study concluded that hybrid fixation provided

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better stabilization values compared to plate fixation.[28]

The use of resorbable materials has increased in fixation systems due to complications such as infection, inflammation, and toxic reactions associated with titanium and stainless steel fixation systems.[21,29]

Ueki et al. evaluated the stability of titanium plate and resorbable plate fixation after SSRO in a sheep mandibular model. The study found no recurrence in either group at the end of the first year.[30]

Despite numerous experimental and clinical studies on fixation systems after SSRO, there is still no consensus on the most ideal method among the fixation techniques. This indicates that the effort to determine the most suitable method among existing methods continues.

RESULTS

Since the time SSRO was defined, the choice of fixation type and its rigidity post-operation has remained a subject of debate. Despite clinical applications and experimental/mechanical studies on various fixation systems, an ideal fixation system has not yet been determined.

While immediate stability may provide insights into long-term stability, the applicability and success of a fixation system should be evaluated on a case-by-case basis. In the past, the cause of relapse occurring either early or late was often attributed to the rigidity of the fixation system. Today, condylar resorption can occur due to the inability to correctly position the condyle, leading to relapse. It is believed that maintaining condylar position in cases where the mandible is set back and using semi-rigid fixation can prevent relapse. However, in cases where the mandible is advanced, especially in severe cases, the rigidity of fixation remains important. Various systems are used to increase fixation rigidity, and fixation with three bicortical screws placed in a reverse L configuration, which is the most rigid stabilization method, may not always yield ideal results. This is because of the challenges posed by bicortical screw fixation in clinical practice and the difficulty in positioning the condyle in the ideal position. Therefore, fixation with monocortical screws and miniplate fixation or hybrid systems have become more popular alternatives.

As a general conclusion from these studies, it is evident that the selection of a fixation system tailored to the specific case is critical for the success of the operation. When choosing a fixation system after SSRO, factors such as fixation rigidity, relapse, cost, surgical experience, ease of application, and aesthetic concerns should be taken into consideration.

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