

## Research Paper

# Titanium nickelide metal constructs used in the treatment of mandibular condyle fractures

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### ABSTRACT

**Introduction:** This study investigated the clinical and mechanical effectiveness of titanium nickelide structures in the treatment of mandibular condyle fractures.

**Aim:** The purpose of the study was to substantiate the use of metal structures made of titanium nickelide to increase the effectiveness of fixation methods and accelerate the recovery process in fractures of the mandibular condyle.

**Material and methods:** The study conducted clinical and X-ray observations, including computer topographical analysis and electromyography of the masticatory muscles, and investigated the use of titanium nickelide and titanium mini-plates in the surgical treatment of mandibular condyle fractures to assess their mechanical, biological, and functional properties.

**Results and discussion:** The findings confirmed that titanium nickelide exhibits high mechanical strength, shape memory under thermal exposure, and resistance to corrosion in physiological environments, ensuring accurate and durable fixation. Clinical trials demonstrated the material's biocompatibility, contributing to accelerated bone healing and reduced postoperative complications.

**Conclusions:** Compared to traditional intermaxillary splints, titanium fixators and endoprostheses significantly reduced surgery time and recovery period, offering a safer, more efficient, and economically advantageous treatment option for mandibular condyle fractures.

## 1. INTRODUCTION

The mandibular condyle fracture is one of the most difficult injuries in maxillofacial surgery because it disrupts jaw anatomy and key activities like chewing, speaking, and breathing. Trauma can cause condylar fragment displacement or dislocation, requiring precise and stable stabilisation to heal and restore function. Traditional treatments include stiff fixation materials like stainless steel plates and screws or intermaxillary fixation, which immobilises the jaw with splints or wires. Although effective, these procedures might cause extended recovery durations, discomfort, and problems like infection or fracture non-union. Advanced materials like titanium nickelide have form memory, mechanical strength, and biocompatibility.<sup>1</sup> Titanium nickelide is a promising material for treating mandibular condyle fractures because it stabilises bone pieces, reduces displacement and inflammation, and speeds recovery.

In maxillofacial surgery, the issue of choosing materials for fixing bone fragments in fractures of the condyle of the lower jaw is relevant, since the speed of recovery and minimising the risk of complications depend on their properties. Safavi et al.<sup>2</sup> showed that titanium nickelide possessed unique biomechanical characteristics that contributed to a more reliable fixation of bone fragments compared to conventional materials. They also noted that the use of this material helped to shorten the recovery time of patients after injuries. Witkowska et al.<sup>3</sup> proved that titanium nickelide significantly accelerated the rehabilitation of patients due to its ability to restore its original shape under the influence of temperature. Their research also emphasised the importance of an individual approach when using titanium for the treatment of complex fractures. Manik and Sahu<sup>4</sup> investigated the biocompatibility of titanium nickelide and found that it minimised the risk of inflammation and allergic reactions in patients. According to their results, this material significantly reduced the likelihood of implant rejection. Yang et al.,<sup>5</sup> having studied the corrosion resistance of titanium nickelide, came to the conclusion that this material demonstrated high resistance to the effects of physiological fluids, which made it ideal for long-term use in the body. They also noted that corrosion resistance directly affected the durability of the implants. Khattab et al.<sup>6</sup> analysed the mechanical characteristics of titanium nickelide and found that the material could withstand heavy loads, which was important for fixing complex fractures. They also noted that the use of this material improved the effectiveness of surgical interventions due to its high strength.

Kubášová et al.<sup>7</sup> investigated the influence of various methods of titanium nickelide production, indicating that the accuracy of the technological process is critically important to achieve high-quality material with the necessary mechanical characteristics. They also stressed that high-quality manufacturing contributed to improving the reliability of the implants. Zhang et al.<sup>8</sup> showed that even small deviations in the manufacturing parameters of titanium nickelide could significantly affect its properties, which was important for

effective use in surgery. They also noted that compliance with production standards was critical to ensure the safety of using the material.

## 2. AIM

The purpose of the study was to evaluate the effectiveness and safety of various surgical methods for the treatment of fractures of the condyle of the lower jaw with severe injuries, with special emphasis on the use of bone screw clamps, mini plates, and titanium endoprostheses.

## 3. MATERIAL AND METHODS

Titanium nickelide was tested for treating mandibular condyle fractures using clinical, radiographic, and electromyographic methods. A careful study of patient data, preoperative imaging (X-ray, CT scans), and postoperative evaluations assessed fixation quality and recovery status. EMG was also used to assess masticatory muscle healing. Laboratory testing examined titanium nickelide's shape-memory, corrosion resistance, and biomechanical strength under pressure. To assess the material's performance, all approaches were ethical and collected qualitative and quantitative data.

From January 2018 to January 2023, 105 surgeries were performed at the Oral and Maxillofacial Surgery Department of the Osh Interregional Clinical Hospital in collaboration with Osh State University and research institutions in Kyrgyzstan. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Only patients with mandibular condyle fractures were included. They were divided into three groups based on fracture type:

- Group 1 (80 patients): condyle base or neck fractures with fragment dislocation;
- Group 2 (20 patients): high condyle neck fractures with articular head dislocation;
- Group 3 (5 patients): complex intraarticular fractures with dislocation.

Patients (90.4% men; age range 14–70) underwent clinical and imaging diagnostics, including X-ray, CT, and electromyography. Surgical interventions were performed under endotracheal anaesthesia within 1–10 days post-injury. Osteosynthesis used titanium mini-plates, screws (KLS Martin), and condylar endoprostheses (Konmet, Moscow). Various titanium nickelide structures, such as staples, plates, and meshes, were evaluated for fixation and functional restoration.

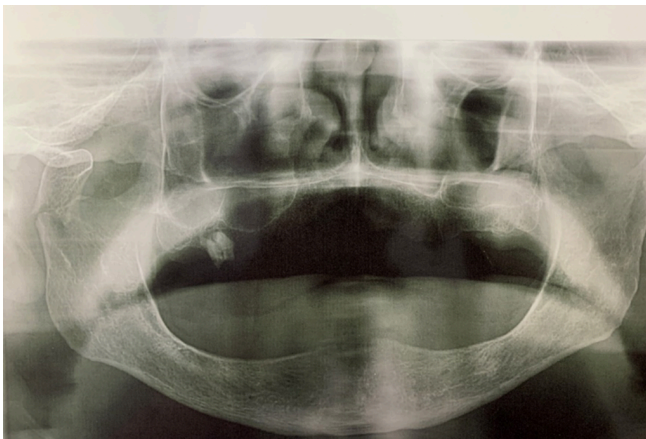
## 4. RESULTS

During the operation, an incision was made in the skin around the corner of the lower jaw, after which the soft

tissues were sequentially dissected, the masticatory muscle was separated, and the branch of the lower jaw and the fracture area were exposed. After assessing the displacement of the bone fragments, they were repositioned. A mini-plate was selected that was most suitable for fixing fragments in shape and size. While maintaining the correct position of the bone fragments, they were fixed using mini plates and bone screws. The wound was sutured in layers, while drainage was left for 1–2 days. In case of a bilateral fracture, osteosynthesis was performed from the opposite side.

Patients from Group 1 underwent osteosynthesis of fragments of the condyle of the lower jaw using titanium mini-plates, which were fixed with titanium screws. Of the 80 patients, 30 (37.5%) had bilateral fixation, and 50 (62.5%) had unilateral fixation. A mini-plate in the shape of the letter “L” was used in 25 patients, a straight implant with 4 holes was used in 35 patients, and two parallel implants were used in 20 patients. This method of surgical treatment of mandibular condyle fractures using titanium structures ensured stable fixation of bone fragments without the need for additional immobilisation with inter-jaw splints, which allowed patients to independently eat and perform active movements of the mandible 2–3 days after surgery, although they were recommended a sparing diet. An example from clinical practice confirms the effectiveness of this approach.

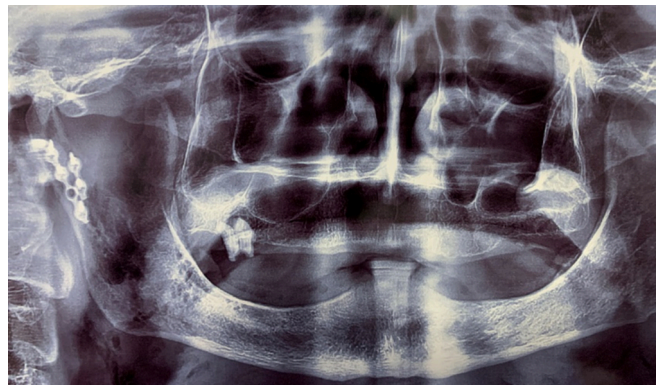
Patient U., 70 years old, was admitted to the department for emergency indications with a diagnosis of “Closed fracture of the mandibular condyle on the right side with displacement and dislocation of the articular fossa”. The preoperative overview panoramic X-ray is shown in Figure 1.



**Figure 1. Preoperative panoramic X-ray examination.**

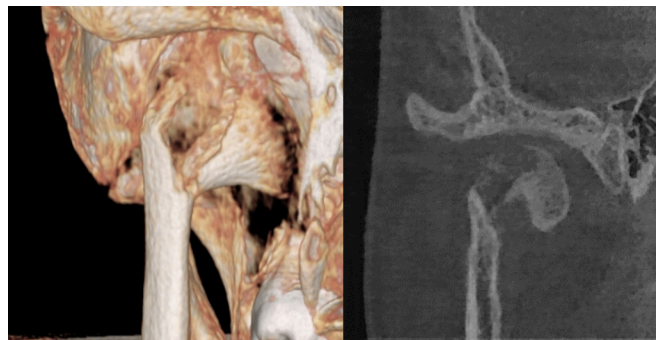
Osteosynthesis was performed using mini plates, which helped to restore the integrity of the lower jaw, as shown in Figure 2. The bone fragments were fixed with two parallel titanium mini plates.

Patients of the second group, who had high comminuted fractures with dislocation of the articular heads, underwent condyle osteosynthesis followed by replantation according to the proposed method (method of surgical treatment of high fractures of the condyle of the mandible with dislocation of



**Figure 2. Osteosynthesis using mini plates: Restoration of the integrity of the lower jaw.**

the articular head, Patent No. 2239).<sup>9</sup> An example of a clinical case: patient D., 38 years old, was taken to the emergency department of Osh Interregional Clinical Hospital with a diagnosis “Closed splinter fracture of the mandibular condyle with damage to the intra-articular capsule and dislocation”, which was confirmed by 3D tomography (Figure 3).



**Figure 3. Fracture of the mandibular condyle with damage to the intraarticular capsule and dislocation.**

The operation was performed under general anaesthesia. After tracheal intubation, an incision was made in the area under the lower jaw, covering the angle of the jaw. The soft tissues were dissected, and the outer surface of the mandibular branch became accessible (Figure 4).



**Figure 4. Extracted fragment with a broken condyle.**

Then the articular capsule and the lateral pterygoid muscle were peeled off, after which the head of the lower jaw was removed from the articular cavity and placed in a 0.9% NaCl solution with an antibiotic (Figure 5).



**Figure 5. Condition after osteosynthesis, the mini-plate is fixed outside the wound.**

Next, an oblique osteotomy of the condyle was performed above the entrance to the mandibular canal. After that, the two fracture fragments were compared and a hole was made through them without damaging the cartilage tissue, after which they were fixed with a titanium nickelide ligature. At the bottom of the fracture, one side of the titanium mini-plate was fixed to the condyle using a screw (Figure 6, 7).



**Figure 6. After condyle replantation and fixation.**



**Figure 7. Panoramic X-ray after surgery, the bite is restored to the correct position.**

The third group of patients with high multifocal and intra-articular mandibular condyle fractures needed endoprosthetics when articular head restoration was unachievable. In benign tumours with temporomandibular joint (TMJ) resection and rib graft autoplasty, endoprosthesis may be indicated, as can autograft lysis, which can change facial contours and tooth occlusal ratios due to lower jaw distal displacement. Patient N., 42, was hospitalised to Maxillofacial Surgery with adamantinoma. Using autostomy, the cancer was excised and rib bone grafted. The graft atrophied and the bone thinned after 6 years, increasing the likelihood of pathological fracture of the autograft replacing the mandibular branch. An X-ray revealed the need for a titanium endoprosthesis to replace the mandibular condyle. Figures 8 and 9 show the patient before and after titanium endoprosthesis autograft and prosthetic replacement.



**Figure 8. Patient's condition before autograft replacement with titanium endoprosthesis.**



**Figure 9. Patient's condition after autograft replacement with titanium endoprosthesis.**

Titanium endoprotheses worked well in complex mandibular fractures when osteosynthesis was impossible or temporomandibular joint head lysis occurred. General condition, sleep, and appetite improved within 2–3 days of surgery. All patients had normal body temperatures and good instant results. Six patients (5.7%) had haematoma suppuration and one had post-traumatic osteomyelitis. Drainage, antiseptics, and antibiotics fixed most issues. Group 2 had one muscle contracture case that resolved after rehabilitation. Long-term outcomes were available for 75 of 105 individuals. Where transient joint pain and limited mouth opening resolved within six months, 70 cases (93.3%) were good and 5 were satisfactory. Imaging confirmed bone alignment and condyle form repair. Complete functional recovery was indicated by +1,100 HU bone density at the fracture location. Electromyography showed recovered masticatory muscle activation in 48 individuals. Better metabolism and bone quality helped under-40 patients recover 3–4 days faster from pain and chewing function than older patients. Healing and functional outcomes were not gender-specific.

## 5. DISCUSSION

Metal structures made of titanium nickelide have proven to be an effective and reliable material in medical practice, especially in maxillofacial surgery. According to the study, the use of titanium nickelide in the treatment of mandibular condyle fractures significantly improves the results of therapy due to such unique characteristics as shape memory, high corrosion resistance, and biocompatibility. These properties allow surgeons to ensure the stability of fixation and minimise the risks associated with prolonged recovery and possible complications. Due to shape-memory and biocompatibility, titanium nickelide constructions recover faster and have fewer difficulties. These structures' shape-memory properties allow them to accurately match the fractured area's anatomical contours, ensuring optimal fixing without undue manipulation and reducing tissue injury during surgery. They absorb and distribute mechanical stresses better due to their superelasticity, reducing implant failure or displacement. High corrosion resistance and biocompatibility reduce inflammation and allergic reactions, minimising infection and rejection. These traits speed healing, reduce post-operative pain, and reduce complications, making recovery easier.

Gareb et al.<sup>10</sup> found that titanium in osteosynthesis provides reliable fixing and durability, but requires removal, which increases surgical interventions. Modern biodegradable polymers allow patients to avoid recurring surgery due to slow absorption. Clinical scenario, patient age, and projected recovery time determine material choice. Kakran et al.<sup>11</sup> found that orthodontic arches and elastic traction reduce treatment trauma, which is important for growing organisms. These procedures stabilise jaw pieces without metal structures. This method reduces complications and makes the child's rehabilitation more comfortable.

Medical and economic factors must be considered while choosing titanium or biodegradable maxillofacial surgery

materials. Although cheaper and more adjustable, titanium structures are more expensive and dangerous to remove. Although more expensive, biodegradable materials reduce treatment injury rates, making them useful in paediatrics, where intervention must be limited. Maxillofacial surgery uses titanium nickelide, stainless steel, cobalt-chromium alloys, and biodegradable polymers. Considering their merits and downsides, titanium nickelide's shape-memory effect, strength, and biocompatibility enable precise fixing and speedier recovery. Surgery to remove after healing is complicated and expensive. Stainless steel and cobalt-chromium alloys are strong but less flexible and may cause discomfort. While more expensive, biodegradable polymers degrade over time, reducing the need for future treatments and patient intervention. Paediatric patients that need trauma reduction and fewer treatments benefit from these materials, despite their higher cost. For better patient outcomes, medical and economic factors should determine material selection.

Using titanium nickelide for osteosynthesis has various benefits. Studies have revealed that its temperature-induced shape restoration makes surgery easier. This allows accurate design adaptation to the patient's anatomy, making it crucial for treating lower jaw condyle fractures. Thus, surgery time is reduced and bone fragment fixation accuracy is improved, restoring jaw functionality sooner. Titanium nickelide has form memory, high strength, and biocompatibility, however temperature sensitivity and manufacturing problems must be considered. Titanium structure removal after healing and accompanying surgical risks can also be negatives. These aspects may increase expenditures and surgical interventions, especially compared to biodegradable materials that disintegrate naturally. Thus, titanium nickelide is a successful treatment for mandibular condyle fractures, although these limits should be noted in practical practice.

Nickel-titanium structures must meet strict production and material quality standards for surgical safety and efficacy. To preserve form memory and superelasticity, alloy composition, production techniques, and post-manufacturing treatments must be precisely controlled. Testing, including fatigue and corrosion resistance, guarantees that these structures can tolerate mechanical forces and hostile physiological conditions. In addition, surface treatments or coatings that reduce inflammation or allergic reactions improve biocompatibility and speed up patient healing. To maximise nickel-titanium structure therapeutic benefits and minimise problems, these conditions are essential.

Schäfer et al.<sup>12</sup> stated that superelasticity and shape memory effect must be considered while examining nickel-titanium tools. Many advanced experimental models simulate clinical load conditions. The lack of commonly acknowledged testing standards may make it difficult to compare results and apply new medical practices. Zhao et al.<sup>13</sup> demonstrated that an arc-shaped nickel-titanium connector can respond to physiological motions and fix ligaments. The shape memory effect restores anatomical position without correction. Compared to metal fastening parts, this method eliminates problems and speeds rehabilitation.

These results confirm the above study by showing nickel-titanium materials' great dynamic load efficiency. Their extraordinary elasticity and fatigue resistance make them ideal for medical applications that require flexibility and durability. In clinical settings when the intervention area's anatomical intricacy and long-term functionality must be considered, this is crucial. Titanium nickelide biocompatibility is also crucial to treatment success. The substance was safe for the body after patients reported no significant rejections. Inflammation and allergic reactions can be reduced to decrease infection and implant rejection. This greatly improves prognosis and speeds recovery.

Mohammed et al.<sup>14</sup> observed that current research aims to make titanium nickelide-based alloys biocompatible by coating or adding corrosion-reducing components. These enhancements limit nickel ion release, which might trigger patient responses. This boosts the safety and longevity of the materials, making them more flexible in medical practice. Di Spirito et al.<sup>15</sup> found that titanium oxide or biologically active coatings considerably reduce inflammation. For orthodontics, extended device exposure in the mouth raises the risk of allergic responses. Innovative titanium nickelide surface treatment methods maximise biocompatibility and comfort, reducing orthodontic replacement.

These findings support the previous section's claims that titanium nickelide treatment greatly enhances biocompatibility and minimises adverse responses. The research shows that protective coatings or alloying additives reduce nickel ion release, reducing irritation and allergic responses. It's crucial to improve medical materials for general use. Titanium nickelide metal structures' durability has helped repair mandibular condyle fractures. X-ray investigations have revealed that such structures remain stable under sustained jaw apparatus mechanical stress. Complex fractures require implants that can sustain physical exercise without losing their characteristics.

Liu et al.<sup>16</sup> found that mechanical and thermal resistance plus shape and functioning determine metal structure durability. Strong and self-healing under plastic deformation, high-titanium alloys perform well. However, excessive loads or harsh conditions can cause fatigue failures, therefore all operational parameters must be considered in structure design and use. In maxillofacial surgery, titanium nickelide metal constructions are new and promising. They improve mandibular condyle fracture treatment by providing dependable fixation, accelerating rehabilitation, and decreasing complications. The material's endurance and biocompatibility make it essential for treating complex injuries that require precise and reliable surgical intervention.

## 6. CONCLUSIONS

- (1) Titanium nickelide structures provide reliable fixation for mandibular condyle fractures.
- (2) The material's shape-memory effect ensures precise adaptation during surgery.
- (3) High biocompatibility reduces risks of inflammation and implant rejection.
- (4) Mechanical strength ensures durability and long-term stability under load.
- (5) Surgical outcomes showed a 92.3% success rate with titanium fixators.
- (6) Mini-plates eliminate the need for intermaxillary immobilization, promoting faster recovery.
- (7) Titanium nickelide offers a safer, more efficient, and cost-effective treatment option.
- (8) Early rehabilitation and independence are possible due to faster recovery times.
- (9) Titanium nickelide is recommended for precise fixation and accelerated healing.
- (10) Further research is needed to explore long-term outcomes in patients with chronic conditions.

### Ethics approval

None declared.

### Conflict of interest

None declared.

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### Author Contributions

Study design: AE, DE, NA

Data collection: IT, NK, DE, NA

Statistical analysis: IT, NK

Data interpretation: AE, IT, DE, NA

Manuscript preparation: AE, IT, NK, DE

Literature search: AE, NA

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