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Therapeutic Potential Of Mumiyo In Enhancing Bone Healing Following Osteosynthesis In Rabbits

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Abstract. *This study evaluates the therapeutic effect of mumiyo in combination with osteogenon for treating bone fractures in rabbits after intramedullary osteosynthesis. Rabbits were monitored using standard veterinary clinical methods, observing physiological indicators such as appetite, body temperature, respiratory and pulse rates, as well as localized signs at the fracture site, including swelling, pain sensitivity, and skin temperature changes. Results showed that mumiyo-treated rabbits exhibited faster clinical recovery compared to the control group. By day seven post-surgery, these rabbits had normalized appetite, stable body temperature, and physiological parameters, with improved weight-bearing on the affected limb and no signs of pain or exudation. Hematological analysis revealed increased hemoglobin and erythrocyte levels, suggesting mumiyo's potential to stimulate hematopoiesis, which may support osteogenesis. This indicates that mumiyo, especially when combined with osteogenon, accelerates recovery and enhances both systemic and local healing responses. These findings suggest that mumiyo could serve as an effective adjunctive therapy in veterinary orthopedic practice, warranting further investigation through controlled studies.*

1. INTRODUCTION

Improper alignment of bone ends can lead to leg tilt, impaired function, pathological mobility at the fracture site, and other detrimental consequences. Bone osteosynthesis often enables an animal with a broken limb to bear weight on the affected leg post-surgery. Properly performed osteosynthesis ensures the repositioning of the bone, stabilizing the fragments and promoting their union. In recent years, osteosynthesis has gained significant importance in veterinary practice, with the introduction of new materials and improvements in the existing methods of bone immobilization [7; 10-11-b., 10; 7-8 P.].

The healing of broken bones is accompanied by the formation of new tissue, leading to the formation of bone consolidation. The healing time for broken bones can vary from several weeks to several months, depending on factors such as the size and age of the animal, the condition of the organism, changes in local tissues, the location, and the type of fracture.

Bone tissue regenerative therapy should encompass three essential elements of bone regeneration: osteogenesis, osteoinduction, and osteoconduction. Osteogenesis refers to the ability of bone-forming cells to produce new bone. Osteoinduction is the process where biological mediators stimulate the recruitment of mesenchymal stem cells to the injury site, which then differentiate into established bone cells. Osteoconduction is the physical property of a matrix that facilitates vascular penetration and the formation of new bone [2; 20-27 p., 3; p.10.]. Thus, the introduction of additional bone-forming agents into the body to ensure bone regeneration reduces treatment duration and promotes the early recovery of musculoskeletal function. Currently, experiments focused on the use of essential and economically effective treatment methods are considered highly relevant.

As a potent biostimulant, the Mumiyo drug enhances physiological functions in the body, facilitating the transfer of mineral substances from reserves to the bloodstream, naturally directing them towards the fracture site [8; 22-p; 9; 17-p.]. The goal of this study was to use Mumiyo preparation in experiments to observe the formation of bone scales.

2. Materials and Methods: For the experiments, 9 rabbits of a local breed, each 12 months old, were selected. Osteosynthetic surgery was performed on these rabbits to treat hip bone fractures. A treatment protocol was followed, after which the rabbits were divided into three groups and treated according to the scheme outlined in (Table 1)(n=3).

Table 1. Treatment Options for Experimental Groups and Control Group.

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№	Experimental Groups	Treatment Options
1	**Experiment Group 1**	Lincomycin - 1.0 ml, 1 time i/m, 10 days, Calcium gluconate - 1 tablet orally, 2 times a day, 25 days, Vitamin D3 - 1500 IU, added to feed, 1 time, 15 days, Mumiyo - 1 tablet, crushed and mixed in 5 ml of water, 2 times a day, 15 days, 2% iodine for wound treatment, 2 times a day, 10 days.
2	**Experiment Group 2**	Lincomycin - 1.0 ml, 1 time i/m, 10 days, Calcium gluconate - 1 tablet orally, 2 times a day, 25 days, Vitamin D3 - 1500 IU, added to feed, 1 time, 15 days, Osteogenon - 1/2 tablet, 2 times a day, 15 days; 5. 2% iodine for wound treatment, 2 times a day, 10 days.
3	**Control Group**	Lincomycin - 1.0 ml, 1 time i/m, 10 days, Calcium gluconate - 1 tablet orally, 2 times a day, 25 days, Vitamin D3 - 1500 IU, added to feed, 1 time, 15 days, 2% iodine for wound treatment, 2 times a day, 10 days.

During the treatment period, clinical and hematological examinations were conducted on the rabbits.

3. Results and Discussion: Intramedullary Osteosynthesis Technique for Bone Fractures in Rabbits

The intramedullary osteosynthesis procedure was carried out in the following sequence:

Fixation and Anesthesia: The rabbit was secured in a recumbent position. Both general and local (regional) anesthetic techniques were employed. For general anesthesia, 2% Xylanite and 2% Ketamine were administered intravenously at a dosage of 0.1 mg/kg. For local anesthesia, 0.5% Novocaine solution was applied by layer-wise infiltration (saturation method) along the incision line, with a total volume of 10 ml. The steps for surgical site preparation and the required instruments were organized as previously described.

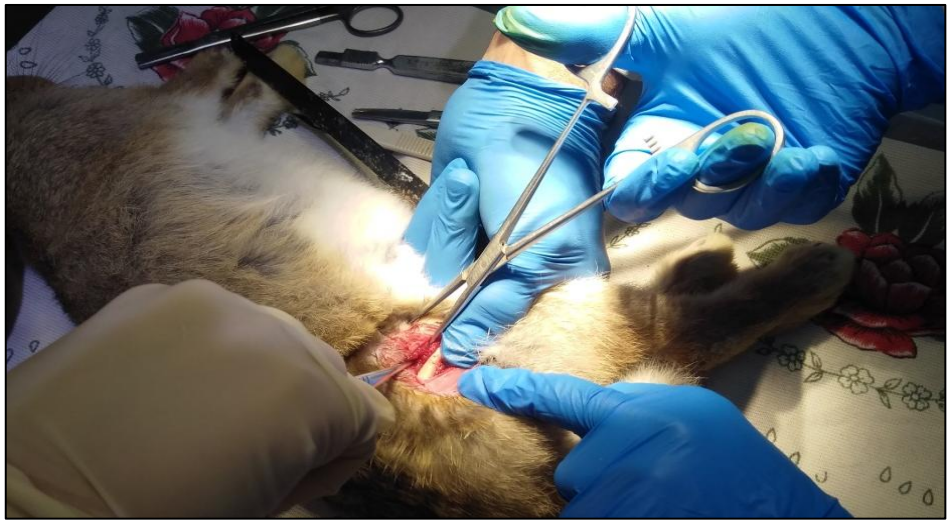

Figure 1. Technique of Performing Intramedullary Osteosynthesis in Femoral Bone Fracture in Rabbits.

Operation Technique: A skin incision was made parallel to the longitudinal axis of the femur, with a length ranging from 6 to 8 cm, depending on the size of the animal. After incising the skin and subcutaneous tissue, both the superficial and deep fasciae were dissected to expose the muscle layer. Hemostasis was performed to stop venous bleeding prior to muscle incision. Once all soft tissues were incised down to the bone, a raspatory was used to carefully separate the adhered tissues from the bone surface. The periosteum was incised using a scalpel and lifted away with a raspatory.

Next, an artificial fracture was created in the femur using a surgical saw. The proximal bone fragment was then mobilized and, if needed, lifted with the help of bone hooks. A sharp metal rod (shaft) was inserted

into the medullary canal of the proximal fragment using a hammer, in a bottom-up direction. Once the shaft exited through the proximal epiphysis, its distal end was aligned with the medullary canal of the distal bone fragment. The bone fragments were repositioned anatomically, and the shaft was driven downward into the distal epiphysis to stabilize the fracture.

The protruding upper end of the shaft was trimmed, leaving approximately 0.5 cm exposed. After callus formation, the shaft was later removed through the remaining exposed section. Upon completing the osteosynthesis, a continuous suture was applied to the muscle layer, followed by a continuous interrupted suture on the skin. Skin sutures were removed 7–10 days after surgery.

Clinical Observations During Osteoreparative Treatment Following Osteosynthetic Surgery in Rabbits: Rabbits involved in the experiment were clinically evaluated using standard veterinary diagnostic methods after undergoing intramedullary osteosynthesis. The evaluation focused on general health indicators such as appetite, body temperature, pulse rate, respiratory rate, and localized signs at the fracture site, including limb condition, local temperature, pain, swelling, and exudate presence (fig.1).

In the initial days post-surgery, all three groups of rabbits exhibited reduced appetite, elevated body temperature, and a mild increase in both pulse and respiratory rates. At the fracture site, increased local temperature, swelling, hyperemia, pain upon palpation, and minor hemorrhagic exudate were commonly observed.

In the control group, preoperative body temperature averaged 38.9 °C, which rose to approximately 39.9 °C by the second postoperative day. The pulse rate increased from a baseline average of 201 beats per minute to 238, while the respiratory rate rose from an average of 40 to 55 breaths per minute. Additionally, local symptoms such as elevated temperature, swelling, hyperemia, pain, bone crepitus, and hemorrhagic exudation were noted at the fracture site. A pronounced limp was observed in the affected limbs. By the second day of observation, a marked decline in appetite was a common clinical sign among the rabbits in this group.

The body temperature of rabbits in the first experimental group remained within the physiological range before surgery, averaging 39.2 °C. By the second day post-operation, it rose to an average of 40.0 °C. The pulse rate increased from an initial average of 210 to 244 beats per minute, and the respiratory rate rose from 45 to 58 breaths per minute. At the fracture site, localized symptoms such as elevated temperature, swelling, hyperemia, pain upon palpation, bone crepitation, and mild hemorrhagic exudation were observed. A pronounced limp on the fractured limb was evident. By the second postoperative day, general appetite loss was characteristic in this group.

Table 1. Clinical Indicators of Body Temperature, Pulse, and Respiration Rate in Different Groups During Treatment.

Group	Treatment Day	Body Temperature (°C)	Pulse (per minute)	Breathing Rate (per minute)
Control Group	Pre-operation	38.9 ± 0.04	201 ± 3.1	40.2 ± 0.5
	Day 2	39.9 ± 0.55	238 ± 1.89	55 ± 1.04
	Day 7	39.5 ± 0.15	226 ± 1.6	49 ± 0.7
	Day 10	40.0 ± 0.35	218 ± 1.8	50 ± 0.6
Experiment Group 1	Pre-operation	39.2 ± 0.06	210 ± 2.5	45 ± 0.45
	Day 2	40.0 ± 0.54	244 ± 0.87	58 ± 0.15
	Day 7	39.1 ± 0.12	216 ± 1.5	48 ± 0.45
	Day 10	38.9 ± 0.25	194 ± 3.6	44 ± 0.25

Experiment Group 2	Pre-operation	39.1 ± 0.65	198 ± 3.2	48 ± 0.4
	Day 2	40.0 ± 0.05	241 ± 2.05	61 ± 0.05
	Day 7	39.3 ± 0.18	220 ± 2.6	45 ± 0.32
	Day 10	39.0 ± 0.14	200 ± 3.4	43 ± 0.15

The body temperature of rabbits in the second experimental group also remained within the physiological limit preoperatively, averaging 39.1 °C, and increased to an average of 40.0 °C by the second postoperative day. The pulse rate accelerated from an initial 198 to 241 beats per minute, and the respiratory rate increased from an average of 48 to 61 breaths per minute. Local findings at the fracture site included increased temperature, swelling, hyperemia, palpation pain, crepitation, and mild hemorrhagic exudation. A marked limp was noted on the affected limb. On the second day of the experiment, rabbits in this group exhibited complete appetite loss.

From the third day after surgery, the general condition and appetite of rabbits in all groups began to improve. A mild "base" limp persisted in the affected limbs. At the fracture site, slight local temperature increase, edema, hyperemia, pain on palpation, and mild hemorrhagic exudation were still observed.

By the seventh day, clinical parameters—including appetite and body temperature—normalized in both experimental and control groups. Rabbits in all three groups showed mild weight-bearing on the fractured limb with a minimal limp. Palpation of the fracture site no longer induced pain or exudation, and hair regrowth in the area had begun.

On the tenth day, rabbits in the control group were in moderately good condition. Appetite was fully restored, but body temperature showed a slight increase compared to day seven (40.0 ± 0.35 °C). A mild limp remained, and palpation of the fracture site revealed slight pain and a small amount of fibrinous exudate. Hair regrowth continued.

In contrast, rabbits in the first and second experimental groups demonstrated good overall condition and normal weight. Appetite, body temperature, pulse, and respiratory rate remained within physiological norms. No signs of pain, exudation, or lameness were observed.

By the thirtieth day of the study, musculoskeletal function was fully restored in all rabbits. The intramedullary pins were removed from the femurs. In experimental groups, body temperature, pulse rate, respiratory frequency, mucous membrane condition, and hair coat were within normal limits. However, in the control group, two rabbits still presented with minor fibrinous exudate at the proximal epiphysis, near the site of rod insertion.

Some Morphological and Biochemical Indicators of the Blood of Rabbits Undergoing Osteosynthesis and Osteoreparative Treatment:

Previous scientific studies have established that bone lesions are accompanied by specific changes in the blood system [93; pp. 176–177]. Today, the metabolic status of the skeletal system is evaluated based on clinical and laboratory diagnostic results [4; pp. 49–52].

One of the most important characteristics of bone tissue is its ability to completely regenerate both structurally and functionally after injury [1; pp. 69–72]. Given the well-known close relationship between bone formation and hematopoiesis, the dynamic composition of formed blood elements can serve as an informative indicator of the intensity of reparative osteogenesis. This methodological approach allows for the assessment of hematological changes occurring during bone regeneration, particularly under osteosynthesis conditions.

In our experiments, peripheral blood samples (0.5–1 ml) were collected from the ear vein of rabbits and analyzed for both morphological and biochemical parameters. These indicators were then compared with baseline values obtained from clinically healthy rabbits as per the criteria established by Ozegbe et al. [5; pp. 431–437].

The results revealed that, prior to surgery, morphological and biochemical blood parameters in all three groups of rabbits were within physiological limits. However, following femoral bone fracture and

intramedullary osteosynthesis surgery, several specific alterations in these indicators were recorded, reflecting the body's response to bone injury and subsequent healing processes.

In the control group, the average preoperative hemoglobin concentration was 108.0 ± 18.7 g/L. By the second day post-surgery, it had decreased by 4.6 g/L, reflecting the body's response to surgical trauma and blood loss. This reduced level persisted until the 10th day. By the 20th day, hemoglobin began to recover, reaching 92.7 ± 6.04 g/L, and by the 30th day, it surpassed the baseline, reaching 97.7 ± 11.9 g/L ($p < 0.05$), an increase of 2.7 g/L compared to the original level.

In the first experimental group, hemoglobin levels averaged 107.0 ± 34.08 g/L prior to surgery. A decrease of 2.7 g/L was recorded by day 2, and a further drop of 5.9 g/L was observed by day 10. Hemoglobin levels exhibited a gradual upward trend from day 20, and by day 30, they had increased by 3.3 g/L compared to the initial value ($p < 0.05$).

In the second experimental group, preoperative hemoglobin levels averaged 119.0 ± 13.3 g/L. A substantial decrease of 28.8 g/L was observed on the second day post-surgery. Despite a recovery trend beginning on day 10 (117.0 ± 20.9 g/L), the original value was not fully restored by day 30 (124.5 ± 27.3 g/L).

Regarding erythrocytes, the preoperative count in the control group averaged 3.7 ± 0.42 million/μL. This number dropped to 3.0 ± 0.46 million/μL by the second day after surgery. A gradual increase followed, and by the end of the experiment, the erythrocyte count exceeded the baseline by 0.6 million/μL.

In the first experimental group, the erythrocyte count in peripheral blood averaged 3.6 ± 0.29 million/μL prior to surgery. On the 2nd and 10th days post-operation, the count decreased by 0.3 million/μL. A slight upward trend was observed by the 20th day, and by the 30th day, the erythrocyte level had surpassed the initial value by 0.4 million/μL, reaching 4.0 ± 1.33 million/μL ($p < 0.05$).

In the second experimental group, preoperative erythrocyte levels averaged 3.9 ± 0.74 million/μL. This count dropped to 3.6 ± 0.47 million/μL on the 2nd day post-surgery. From the 10th day onward, the erythrocyte count increased (3.7 ± 0.55 million/μL), eventually reaching 4.2 ± 0.70 million/μL by day 30, exceeding the initial value.

Regarding leukocytes, the control group rabbits had an average preoperative leukocyte count of 4.5 ± 0.68 thousand/μL. On the 2nd day following surgery, this number rose to 5.4 ± 1.13 thousand/μL. Elevated leukocyte levels persisted through the 20th day, reaching the peak of leukocyte dynamics during the experimental period. This prolonged leukocytosis suggests a purulent inflammatory process at the injury site. Although the leukocyte count decreased by 1.0 thousand/μL by the end of the experiment, it remained 2.6 thousand/μL above baseline ($p < 0.05$).

In the first experimental group, the leukocyte count in peripheral blood averaged 5.8 ± 1.46 × 10^3/μL prior to surgery. By the 2nd day post-operation, this value slightly increased to 5.9 ± 1.18 × 10^3/μL, reaching 6.0 ± 0.28 × 10^3/μL by the 10th day. A modest decline was noted by the 20th day, and by the 30th day, the leukocyte count had decreased by 0.7 × 10^3/μL compared to baseline ($p < 0.05$). Overall, there were no significant elevations in leukocyte levels in this group throughout the experiment.

In the second experimental group, the leukocyte count increased from a preoperative average of 5.0 ± 0.76 × 10^3/μL to 5.3 ± 0.70 × 10^3/μL on the 2nd day post-surgery. A progressive rise was noted by day 10 (6.0 ± 0.97 × 10^3/μL), with a final count of 5.7 ± 0.87 × 10^3/μL on day 30, which was 0.7 × 10^3/μL above the initial value. However, these fluctuations were minor, and overall leukocyte dynamics remained relatively stable. A slight neutrophilia and a mild decrease in monocyte levels were noted in the leukocyte differential.

The erythrocyte sedimentation rate (ESR) in all three groups remained within normal limits prior to surgery. In the control group, ESR averaged 1.7 ± 0.80 mm/h preoperatively. By the 2nd day after surgery, this rate increased to 5.7 ± 0.76 mm/h. A significant prolongation was observed on the 10th day (14.7 ± 0.83 mm/h), exceeding physiological limits. On the 20th day, the ESR further increased to 16.3 ± 0.80 mm/h, then slightly declined to 12.0 ± 1.39 mm/h by day 30. This extended ESR is a clear indicator of postoperative inflammatory response and tissue injury, as a prolonged ESR is commonly associated with systemic inflammation.

In the first experimental group of dogs, the erythrocyte sedimentation rate (ESR) remained within physiological limits before surgery, averaging 2.7 ± 0.60 mm/h. On the 2nd day post-operation, the ESR increased by 2.0 mm/h from baseline, reaching 4.7 ± 0.80 mm/h. A significant elevation was observed on the 10th day, with ESR peaking at 14.7 ± 0.91 mm/h. The marked rise in ESR over a short period

following surgery indicates the organism's active response to surgical trauma and the inflammatory processes accompanying healing. By the 30th day, the ESR had declined to 5.0 ± 0.31 mm/h, approaching normal physiological levels, suggesting substantial recovery.

In the second experimental group, ESR was also within normal range prior to surgery, averaging 4.0 ± 1.0 mm/h, and showed no significant change on the 2nd day (4.0 ± 0.27 mm/h). However, by the 10th day, ESR sharply increased to 13.31 ± 1.2 mm/h and continued to rise, reaching 15.7 ± 1.16 mm/h on the 20th day. This prolonged elevation is indicative of a continuing inflammatory response. By the 30th day, ESR had normalized, returning to baseline levels (4.0 ± 0.79 mm/h), suggesting resolution of inflammation and recovery of physiological function.

Comparative analysis of the data indicates that ESR rose more significantly and remained elevated longer in the control and second experimental groups than in the first experimental group. These findings support the conclusion that a stronger inflammatory response persisted in the control and second groups, whereas recovery occurred more rapidly in the first experimental group.

Experiments have shown that following bone fractures and osteosynthesis in rabbits, several significant changes occur in their blood morphology. Specifically, erythropenia (a decrease in the number of red blood cells) and leukocytosis (an increase in white blood cells) were observed. Additionally, characteristic signs such as decreased hemoglobin levels and prolonged erythrocyte sedimentation rate (ESR) were noted, indicating the physiological response to both the injury and the surgical intervention.

CONCLUSIONS:

1. The first experimental group, which was treated with the mummy drug, exhibited a notable increase in the erythrocyte count on the 20th day post-operation. By the 30th day, the number of erythrocytes in this group had exceeded baseline levels, indicating a positive effect on blood cell production.
2. The control and second experimental groups showed a sharp increase in erythrocyte sedimentation rate (ESR), with values significantly higher than those observed in the first experimental group. This suggests a more pronounced inflammatory response in these groups, highlighting the anti-inflammatory effects of the mummy drug in the first group.
3. The close association between bone tissue formation and blood cell synthesis underscores the utility of dynamic hematological indicators as a means to assess the intensity of reparative osteogenesis. Changes in blood cell composition provide valuable insight into the healing process following bone fractures and surgical intervention.
4. Based on the findings, the oral administration of the mummy preparation, at a dosage of one tablet twice daily for 15 days, effectively stimulates bone repair and can be recommended as a supportive treatment to promote the formation of bone tissue following fractures.

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