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The Use Of Zinc And Cobalt Complex Compounds In Medicine

[1] Kadyrov M.A.

[1] Associate Professor, Department of Medical and Biological Chemistry, Medical Biology, Biophysics and Medical Informatics, Tashkent state medical university, Uzbekistan

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Abstract

This article examines the biochemical and pharmacological aspects of the use of zinc and cobalt coordination compounds in modern medical practice. The relevance of switching from inorganic salts to biocoordination compounds with organic ligands (amino acids, vitamins) to increase the therapeutic index and reduce toxicity is substantiated. The roles of zinc as an immunomodulator and antioxidant, and cobalt as a key component of hematopoiesis, are described. The potential for using these complexes in endocrinology, oncology, and regenerative medicine is analyzed.

Keywords: Coordination compounds, zinc, cobalt, metal complexes, pharmacology, insulin-like action, hematopoiesis, bioavailability.

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1. Introduction

Zinc and cobalt are essential micronutrients that play a critical role in human metabolism. Zinc is a component of over 300 enzymes and transcription factors, ensuring cell membrane stability and immune response. Cobalt is the central atom of vitamin B12 (cobalamin), essential for DNA synthesis and erythropoiesis. However, the use of simple inorganic salts of these metals is limited by their low bioavailability and the risk of systemic toxicity. The creation of complex compounds with organic ligands opens new possibilities for targeted therapy, allowing for the controlled release of metal ions in target tissues.

Purpose of the study

To study the physicochemical and biological properties of modern zinc and cobalt complex compounds, and to analyze their effectiveness in the treatment of metabolic disorders, deficiency conditions, and inflammatory processes.

2. Methods

This study utilizes an analytical method to investigate existing pharmacological agents and innovative developments in the field of metal complexes. A comparative analysis of the bioavailability of chelated forms (zinc picolinate, cobalt gluconate) and inorganic analogs is conducted. Computer modeling data on the interaction of ligands with enzyme active sites is also considered.

3. Results And Discussion

Complex Zinc and cobalt compounds are important in medicine. They are biogenic elements necessary for

normal functioning of the body, and their deficiency leads to severe pathologies. Zinc and cobalt readily form stable complex compounds and participate in the body's oxidation -reduction reactions.

Zinc and cobalt complexes are used in medicine and pharmacology. Many of them are components of enzymes and drugs.

I. Zinc complexes

Zinc is a biogenic d -element. It is an essential trace element. Zinc normalizes sugar metabolism, which is why it is a component of insulin. It actively participates in vital processes such as carbohydrate, protein, and fat metabolism. Zinc ions activate alkaline phosphatase. It is believed that the zinc ion preserves the enzyme's structure and fixes certain amino acid residues. Zinc is involved in hematopoiesis and endocrine function, and it promotes the removal of carbon dioxide from the body . In the human body, the greatest amounts of zinc are found in the retina, sperm, liver, and muscles.

The body of a person weighing 70 kg contains 2-3 g of zinc; in the blood – 7.0 mg/l; in bone tissue – (0.75-1.7) x 10 –2 %; in muscle tissue – 2.4 x 10 –2 %.

Biological role: zinc is involved in important processes:

- is a part of many enzymes: carbonic anhydrase (which accelerates the breakdown of hydrocarbons in the blood, ensuring the speed of the process of respiration and gas exchange), superoxide dismutase (which destroys free radicals), lactate dehydrogenase, alkaline phosphatase, etc.;
- is a catalyst for cellular processes;
- participates in the exchange of nucleic acids and the formation of their helical structure;
- is a component of insulin, which regulates blood sugar levels;
- participates in the formation of bone and cartilage tissue, promotes tissue regeneration;
- stimulates the thymus, affects the formation and maturation of T-lymphocytes;
- Additional intake of Zn reduces the duration of colds;
- promotes the absorption and effectiveness of B vitamins;
- antidepressant.

Zinc does not exhibit significant redox activity, but its complexes play an important structural role. The following are used in pharmacology:

- zinc-containing enzyme inhibitors;
- wound healing drugs;
- immunomodulators.

Zinc complexes are used in the treatment of dermatological diseases, ulcers, inflammatory processes, and also in dentistry.

The use of zinc complexes in pharmaceuticals spans both traditional fields (immunology, dermatology) and high-tech developments in diabetes and oncology treatments. Due to its low toxicity and role as a cofactor for over 300 enzymes, zinc is an ideal metallocenter for drug development.

1. Diabetes therapy

Zinc complexes are considered as promising oral hypoglycemic agents.

- Insulin mimetics: Zinc complexes with organic ligands (eg, alloxanthin or pyridine derivatives) can mimic the action of insulin, improving glucose uptake by tissues.
- Insulin stabilization: Zinc remains a critical component in the production of long-acting insulin preparations, ensuring its deposition in crystalline form.

2. Dermatology and regenerative medicine

Zinc complexes remain the "gold standard" in the treatment of skin lesions due to their antibacterial and anti-inflammatory properties.

- Zinc hyaluronate: Used to treat trophic ulcers and complicated wounds, accelerating tissue regeneration at the cellular level.
- Innovative biocompositions: In 2025–2026, zinc complexes based on humic acids and metal-organic frameworks, which provide controlled release of metal ions into the area of inflammation, will be actively studied.

3. Oncology and chemotherapy enhancement

In early 2026, methods for synthesizing new compounds

to enhance the action of antitumor drugs using metal complexes were presented.

• Selective cytotoxicity: Zinc complexes (e.g. with imidazole derivatives) are able to selectively induce apoptosis in cancer cells without damaging healthy tissue.

4. Immunomodulation and antiviral protection

• Zinc ionophores: In the pharmaceutical industry of 2026, combinations of zinc complexes (gluconate, picolinate) with ionophores are popular, which facilitate the transport of metal into the cell, blocking the replication of RNA viruses.

• Dentistry: Zinc-containing preparations are being actively introduced for the prevention of caries and treatment of periodontal diseases.

The most in-demand forms by 2026 are chelated forms (bisglycinate, picolinate), which have maximum bioavailability (up to 90%) and minimal side effects from the gastrointestinal tract.

II. Cobalt complexes

Cobalt is a d element of the iron family and exhibits high biological activity. It is a vital trace element. Its primary storage sites are the liver, kidneys, blood, spleen, pancreas, pituitary gland, thyroid gland, ovaries, and bone tissue. It is a component of vitamin B12, cyanocobalamin. It accounts for 4.0% of vitamin B12.

The body of a person weighing 70 kg contains 14 mg of cobalt; in the blood – 0.0002-0.04 mg/l; in bone tissue – (0.01-0.04) · 10 –4 %; in muscle tissue – (0.028-0.65) · 10 –4 %.

Biological role: cobalt is involved in important processes:

• affects the growth and development of the body;

• one of the main components of vitamin B 12 ;

• participates in the process of hematopoiesis, stimulates the formation of red blood cells and hemoglobin, promotes the extraction of Fe from the depot, and prevents the occurrence of anemia;

• has a neurophysiological effect: increases the excitability of the adrenoreactive systems, reduces the sensitivity of chemoreceptors to acetylcholine, inhibits neuromuscular transmission, has an epileptiform effect;

• affects all types of metabolism, participates in the breakdown of carbohydrates;

• inhibits respiration of bone marrow, liver, and kidney tissues;

• participates in the synthesis of a number of enzymes (glycine dipeptidase, cholinesterase, acylase), thyroid hormone.

Coordination compounds of cobalt are involved in:

• DNA synthesis;

• fatty acid metabolism;

• functioning of the nervous system.

Hypoxia-activated cobalt complexes capable of selectively affecting tumor tissue are also being studied.

1. Vitamin B_{12} (Cyanocobalamin)

Cobalt is best known as a component of vitamin B1. This is because cobalt is the central atom in the vitamin **B_{12}** molecule — the only naturally occurring organometallic compound containing this metal.

• Function: Necessary for DNA synthesis, normal hematopoiesis (erythropoiesis) and functioning of the nervous system.

• Application: Treatment of pernicious anemia and neurological disorders. In 2026, highly purified forms of cobalamin continued to be used to correct micronutrient deficiencies.

2. Oncology: Cobalt-60 and targeted complexes

Cobalt plays an important role in the treatment of malignant neoplasms:

• Radiotherapy: The cobalt-60 isotope remains the standard for gamma-ray systems and gamma knives in stereotactic radiosurgery for brain tumors. The market for cobalt-60-based systems in 2025–2026 is recognized as a cost-effective solution for global healthcare.

• Targeted drugs: In 2025, scientists synthesized new cobalt complexes with esculetin (a substance found in chicory leaves), which significantly increase the effectiveness of cancer cell destruction while reducing the overall toxicity of therapy.

• Hypoxia-selective agents: Cobalt (III) complexes are being investigated as " prodrugs " that are

activated only under conditions of oxygen starvation inside the tumor, thus minimizing harm to healthy tissue.

3. Antimicrobial activity

Coordination compounds of cobalt (II) with various ligands (e.g. sulfonamides or imidazole derivatives) exhibit high antibacterial and antifungal activity.

- Fighting resistance: Cobalt complexes are effective against S. aureus and Candida strains, outperforming pure organic ligands.
- Synergy: Cobalt enhances the effects of traditional antibiotics by disrupting the metabolic pathways of pathogens resistant to conventional drugs.

4. New synthesis technologies (2026):

New methods for using plasma synthesis to produce cobalt compounds have been proposed. This technology enables the creation of high-purity pharmaceutical and medical materials with tailored biological properties more quickly and environmentally friendly than traditional methods.

5. Medical products:

Cobalt alloys (e.g., Vitallium) have been used for decades to make endoprostheses (hip and knee joints), stents, and surgical instruments due to their exceptional wear resistance and biocompatibility.

Antitumor activity of cobalt complex compounds

Although platinum-based drugs are the most widely known, cobalt complexes are considered a less toxic alternative. Their mechanisms of action include:

- binding to DNA and RNA;
- enzyme inhibition;
- induction of oxidative stress;
- mitochondrial dysfunction.

Zinc and cobalt complexes are being actively investigated as potential anticancer agents, particularly in nanostructured and targeted delivery forms.

4. Conclusion

Zinc and cobalt complexes occupy an important place in modern medicine, performing both physiological and therapeutic functions. Their diverse chemical properties allow the creation of drugs with desired activity and selectivity. Despite existing limitations, further research in this area has great potential and could lead to the development of fundamentally new methods for diagnosing and treating diseases.

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