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EFFECTIVENESS OF TREATMENT FOR VERTEBRAL FRACTURES IN THE CONTEXT OF OSTEOPOROSIS

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Abstract:

Currently, a number of scientific studies are being conducted on the treatment of osteoporotic fractures of the vertebral body. Problems such as the causes of osteoporotic fractures of the vertebral body, the introduction of new diagnostic methods for their diagnosis, the effect of newly created drugs in conservative treatment, the duration of spinal immobilization, and the prevention of secondary complications in patients with long-term immobilization have been studied. A new surgical method of kyphoplasty has been developed to restore the strength of osteoporotic fractures of the vertebral body.

The addition of antibiotics and contrast agents to the bone cements used during kyphoplasty and vertebroplasty procedures has led to a decrease in complications during and after the procedure. Therefore, the fact that methods for calculating the exact volume of bone cement to be injected when restoring the strength of the vertebral body through percutaneous vertebroplasty or kyphoplasty are not sufficiently effective, and solutions for reducing the exposure to X-rays during the procedure are poorly described in the literature, proves that the development of optimal directions for the treatment of osteoporotic fractures of the vertebral body is urgent and important.

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Keywords: Osteoporosis; osteoporotic vertebral fractures; percutaneous vertebroplasty; bone cement volume; bone mineral density; computer-assisted treatment; vertebral compression fractures.

METHODS: In 2018-2024, 60 (100%) patients with osteoporotic vertebral fractures underwent percutaneous vertebroplasty (PVP) at the Department of Neurosurgery of the Multidisciplinary Clinic of the Tashkent Medical Academy and the Center for Advanced Training of Medical Personnel. The patients were aged from 18 to 80. PVP was performed based on the computer application "Calculation of Bone Mineral Density Volume" using data from MSCT/CT images in the first (main) group in 24 (40%) patients, and PVP was performed without using this computer application in 36 (60%) patients in the second (control) group.

The Oswestry Disability Index (ODI) was used to assess the patients' quality of life, and the Visual Pain Scale (VDS) was used to assess their clinical conditions.

The VDS scale, which rates pain on a scale from 0 (no pain) to 10 (intolerable pain), was used to compare preoperative and postoperative clinical conditions. The Oswestry Disability Index (ODI) was used to evaluate quality of life, particularly functional impairments caused by spinal pathology. This scale consists of six sections, with a maximum score of 5 per section. A total score of 100 indicates severe disability, whereas a score of 0 signifies full functional capability. These data were used to compare treatment outcomes before and after intervention.

Results: All patients underwent PVP. The total number of treated vertebrae was 130. Among them, 17 (28.3%) patients had surgery on one vertebra, 26 (43.3%) on two vertebrae, 11 (18.3%) on three vertebrae, 4 (6.7%) on four vertebrae, and 2 (3.3%) on six vertebrae. The overall condition of the patients was assessed using the VDS and Oswestry scales. The results were classified as satisfactory, unsatisfactory, or good. Twenty-two (91.7%) patients in the main group had a "good" result, while 8 (21.6%) patients in the control group achieved a "good" result.

Conclusions: Using the computer program "Calculation of Bone Mineral Density Volume," 24 (40%) of the 60 patients in the first (main) group received PVP with bone cement injection into osteoporotic vertebral bodies. This program was designed to determine the optimal amount of bone cement for injection into osteoporotic vertebrae. In the second (control) group, 36 (60%) out of 60 patients also underwent PVP, but the bone cement was injected without taking into account the program's data. The developed computer program enables accurate determination of the required bone cement volume, ensuring full restoration of spinal support function and a significant regression of pain syndrome (95.8%).

Keywords: osteoporosis; percutaneous vertebroplasty; bone cement.

I.INTRODUCTION

The social significance of osteoporosis is determined by its consequences, which lead to substantial healthcare expenditures and contribute to a high level of disability, including incapacity for work and mortality. The high and continuously increasing prevalence of osteoporosis, along with the development of pain syndrome, deformities, loss of work capacity, and self-care abilities in patients, highlights the importance of this issue for the healthcare system of the Republic of Uzbekistan.

As shown by our analysis of the literature and clinical studies, an unresolved issue remains the calculation of the precise amount of bone cement required for injection into the damaged vertebra to achieve maximum spinal support function. Currently, according to literature from both nearby and distant countries, there is no available data on the exact amount (in milliliters) of cement to be injected into vertebral bodies according to the degree and area of bone damage. Instead, an estimated amount of cement is conventionally determined based on the affected spinal region and the degree of vertebral body compression.

The concept of vertebroplasty was introduced into clinical practice in the 1970s and 1980s as an open surgical procedure, where bone cement was injected to strengthen vertebral bodies before installing stabilizing systems. Today, this method is widely used in neurosurgical practice and vertebrology [1, 2, 4, 5, 6, 8, 12, 13, 14, 16, 20, 23, 24].

According to the literature, there is data on the experience of treating lumbar vertebrogenic radiculopathies in elderly and senile patients [2] and the higher prevalence of osteochondrosis in women [21, 22].

Some surgeons have used this method to fill empty spaces after resection of vertebral body tumors [19].

Percutaneous vertebroplasty was first performed in 1984 by Drs. Galibert and Deramond at the radiology department of Amiens University Hospital in France on a 54-year-old woman with aggressive vertebral hemangioma at C2 [1, 2].

Currently, vertebroplasty widely employs bone cement injection into vertebral bodies [3, 7, 11, 15, 18].

Numerous clinical studies indicate a significant reduction in pain symptoms in approximately 90% of cases of osteoporotic compression fractures [10].

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The estimated volume of cement for injection is generally determined based on the affected spinal segment and the degree of vertebral body compression [9].

Despite the positive outcomes of vertebroplasty for osteoporotic spinal fractures, some unresolved and controversial issues remain.

II.PURPOSE OF THE RESEARCH

The goal is to improve the results of spinal osteoporosis treatment by fully restoring the support of the damaged vertebral body.

III. MATERIALS AND METHODS

The subjects of the study were 60 (100%) patients with vertebral fractures due to osteoporosis who were treated in the neurosurgery departments of the Multidisciplinary Clinic of the Center for Advanced Training of Medical Personnel and the Multidisciplinary Clinic of the Tashkent Medical Academy in 2018-2024. The patients' ages (62.6±4.1) ranged from 18 to 80. Everypatientwithosteoporoticspinalfracturesreceiveda 100% neurologicalandgeneralexamination, aVisualPainScale (VDS) evaluationoftheirclinicalstatus,quality of life assessment using the Oswestry Disability Index (ODI), and instrumental diagnostic studies. The most informative diagnostic methods included spinal X-ray (100%), magnetic resonance imaging (MRI) of the spine (76%), computed tomography and multislice computed tomography (CT/MSCT) of the spine (47%), and X-ray densitometry (RD) of the lumbar vertebrae (40%) in both preoperative and postoperative periods.

All 60 (100%) patients underwent percutaneous vertebroplasty (PVP).

Indications for PVP:

- Presence of pathological vertebral body fractures of varying degrees, without compression of the spinal cord or its roots.
- Presence of intense localized spinal pain not relieved by analgesics.

Localization of osteoporotic vertebrae according to the computer program:

- Thoracic spine: VTh5 (3%), VTh6 (1.5%), VTh8 (6.25%), VTh9 (1.5%), VTh10 (3%), VTh11 (6.25%), and VTh12 (18.25%).
- Lumbar spine: VL1 (14%), VL2 (14%), VL3 (9%), L4 (17%), and VL5 (6.25%).

Approaches used in percutaneous vertebroplasty:

- Transpedicular approach (84 vertebrae).
- Transcostovertebral approach (46 vertebrae).

The total number of treated vertebrae was 130 across 60 (100%) patients who underwent PVP. Among them, 17 (28.3%) patients had surgery on one vertebra, 26 (43.3%) on two vertebrae, 11 (18.3%) on three vertebrae, 4 (6.7%) on four vertebrae, and 2 (3.3%) on six vertebrae.

Volume (ml) of bone cement injected into 130 osteoporotic vertebrae: 1.5 ml (2.3%), 2.0 ml (21.5%), 2.5 ml (6.3%), 3.0 ml (23.04%), 3.5 ml (6.3%), 4.0 ml (20.7%), 4.5 ml (15.3%), 5.0 ml (1.5%), 5.5 ml (0.767%), and 6.0 ml (2.3%).

The computer program "Calculation of Bone Mineral Density Volume" was designed to determine the optimal amount of bone cement for injection into osteoporotic vertebral bodies based on MSCT/CT data.

Every patient was split up into two groups:

- The first (primary) group: 24 (40%) out of 60 patients with osteoporotic vertebral fractures underwent PVP, where the computer program ("Calculation of Bone Mineral Density Volume") was used to determine the precise amount of bone cement for injection into the osteoporotic vertebral bodies.
- Second (control) group: 36 (60%) out of 60 patients underwent PVP with bone cement injection into osteoporotic vertebral bodies, but without considering the data from the computer program.

Before and after surgery, patients' quality of life was evaluated using the Oswestry Disability Index (ODI), and their clinical state was evaluated using the Visual Pain Scale (VDS).

Evaluation of pain using the VDS scale (in points):

- 0 points for no pain
- Two points for mild pain
- Four points for moderate pain
- Six points for severe pain
- Extremely uncomfortable - 8 points
- Excruciating pain: 10 points

Assessing quality of life with the Oswestry Disability Index (ODI):

Six sections, each with a maximum score of five, were used to assess functional deficits brought on by spinal disease. Three categories were applied to the results: good, satisfactory, and unsatisfactory. A minimum score of 0 indicated full functional capacity, while a maximum score of 5 indicated severe disability.

IV. RESULTS

Using the computer program "Calculating Spinal Bone Mineral Density," 52 vertebrae were analyzed for the exact amount of bone cement in 24 (40%) patients in the primary group.

In the primary group (n=24), the amount of injected bone cement per vertebra (total 52 vertebrae) was as follows:

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- 3.0 ml – 8 (15.38%) vertebrae
- 4.0 ml – 20 (38.46%) vertebrae
- 4.5 ml – 18 (34.6%) vertebrae
- 5.0 ml – 2 (3.84%) vertebrae
- 5.5 ml – 1 (1.92%) vertebra
- 6.0 ml – 3 (5.76%) vertebrae

In the control group (n=36), the computer program was not used to determine the bone cement volume. The distribution of injected cement across 78 vertebrae was as follows:

- 1.5 ml – 3 (4%) vertebrae
- 2.0 ml – 29 (37.2%) vertebrae
- 2.5 ml – 8 (10.3%) vertebrae
- 3.0 ml – 24 (30.7%) vertebrae
- 3.5 ml – 8 (10.3%) vertebrae
- 4.0 ml – 5 (6.4%) vertebrae
- 4.5 ml – 1 (1%) vertebra

Clinical Outcomes

22 (91.7%) patients in the primary group and 8 (21.6%) patients in the control group showed "good" results.

In the primary group, two patients (8.3%) and in the control group, twenty-eight patients (78.4%) got "satisfactory" results.

The above-mentioned scales were also used to assess early and long-term postoperative outcomes.

Pain Mitigation (VDS Scale, 0–10)

- Primary group (n=24):
  - 23 patients (95.8%) experienced complete pain relief (0 points)
  - 1 patient (4.2%) had mild pain (2 points)
  - Mean VDS score: 0.13±0.05
- Control group (n=36):
  - 8 patients (22.2%) experienced complete pain relief (0 points)
  - 28 patients (77.8%) had mild pain (2 points)
  - Mean VDS score: 1.55±0.24

Therefore, the primary group experienced a considerably higher rate of full pain regression (95.8%) than the control group (22.2%).

Quality of Life (Oswestry Disability Index - ODI)

In both groups, quality of life improved in the early postoperative period.

- Primary group: Maximum reduction in disability reached 20%
- Control group: Maximum reduction in disability reached 26%

(Diagram 1 illustrates these changes).

These results confirm that the computer-assisted calculation of bone cement volume significantly improves clinical outcomes, leading to better pain relief and quality of life improvements in patients undergoing percutaneous vertebroplasty.

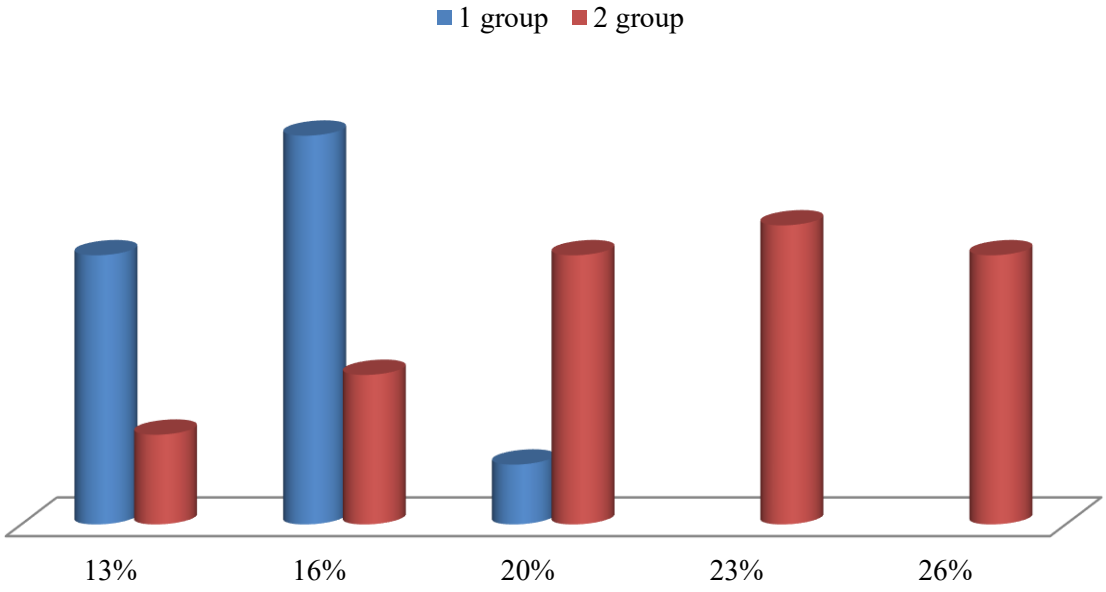

Diagram 1. Indicators of Comparative Assessment of Quality of Life Based on the ODI Scale After Surgery.

From Diagram 1, it is evident that the Oswestry Index did not exceed 26% in any of the operated patients.

The following criteria were used to compare the primary and control groups' treatment effectiveness in the early postoperative period: good, satisfactory, and unsatisfactory.

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Twenty-two (92%) of the patients in the main group had a "good" result, and two (8%) had a "satisfactory" result. In the control group, 28 patients (77.8%) had a "satisfactory" outcome, while 8 patients (22.2%) had a "good" result.

These findings indicate that in the postoperative period, both groups experienced a reduction in pain levels, not exceeding **2 points**.

Similarly, an assessment of the condition of operated patients in the long-term period was conducted in **48 (80%)** out of **60** patients:

- **Main group**: 19 (39.6%) patients
- **Control group**: 29 (60.4%) patients
- Follow-up period: **6 months to 6 years (2018-2024)**

According to the **VDS scale** in the long-term postoperative period:

- **Main group (n=19)**:
  - 0 points: **18 (94.7%)** patients
  - 2 points: **1 (5.3%)** patient (**0.08±0.01**)
- **Control group (n=29)**:
  - 0 points: **14 (48.3%)** patients
  - 2 points: **10 (34.4%)** patients
  - 4 points: **5 (17.3%)** patients (**1.38±0.01**)

Thus, in the long-term postoperative period, **no significant dynamics were observed in the first group**, whereas changes were noted in the second group (**Diagram 2**).

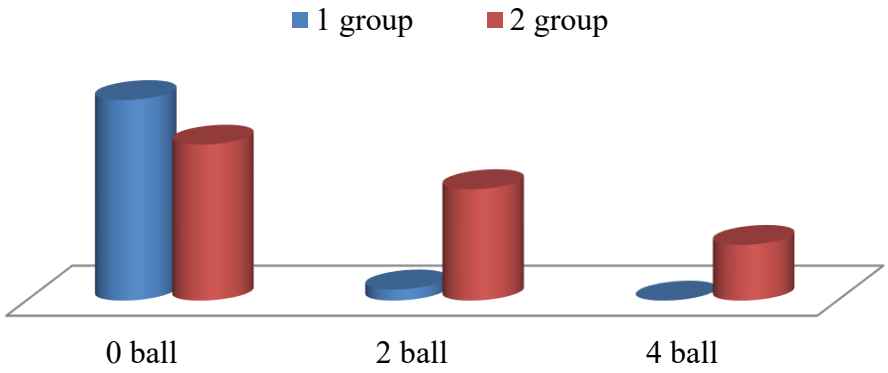

Diagram 2. Long-Term Treatment Outcomes According to the VDS Scale

From **Diagram 2**, it is evident that in the **main group**, no patients experienced **moderate pain (4 points on the VDS scale)**, whereas in the **control group**, 5 patients reported this level of pain.

In the long-term postoperative period, the **Oswestry Disability Index (ODI)** scores were distributed as follows:

- **Main group (n=19):**
  - 6% – **1 (5.3%)** patient
  - 8% – **4 (21.05%)** patients
  - 10% – **3 (15.9%)** patients
  - 13% – **7 (36.8%)** patients
  - 16% – **3 (15.9%)** patients
  - 20% – **1 (5.3%)** patient
  - **Average ODI score: 11.95±0.01**
- **Control group (n=29):**
  - 6% – **1 (3.4%)** patient
  - 8% – **4 (13.4%)** patients
  - 10% – **2 (6.7%)** patients
  - 13% – **4 (13.4%)** patients
  - 16% – **2 (6.7%)** patients
  - 20% – **3 (10.3%)** patients
  - 23% – **3 (10.3%)** patients
  - 26% – **3 (10.3%)** patients
  - 30% – **2 (6.7%)** patients
  - 35% – **3 (10.3%)** patients
  - 40% – **2 (6.7%)** patients
  - **Average ODI score: 19.97±3.24**

These results indicate that in the **main group**, **42% of patients** showed significant improvement in quality of life, with ODI scores below 13%. In contrast, in the **control group**, **only 24% of patients** had ODI scores below 13% (**Diagram 3**).

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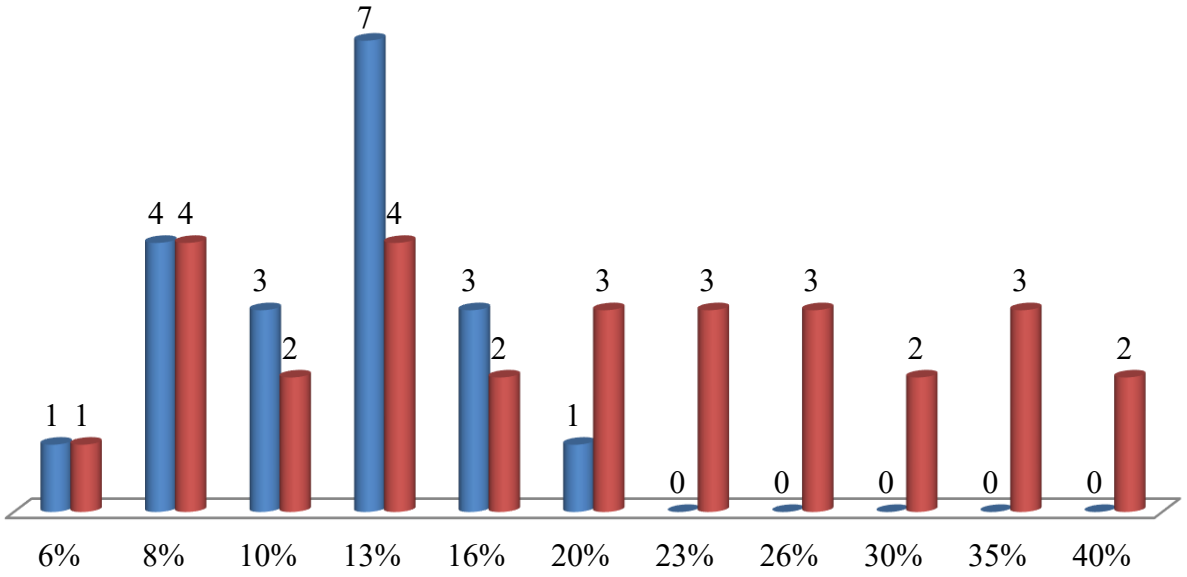

Diagram3. Long-Term Postoperative Outcomes According to the Oswestry Disability Index

From **Diagram 3**, it is evident that in the **first group**, the **ODI did not exceed 20%**, whereas in the **second group**, the **ODI reached up to 40%**.

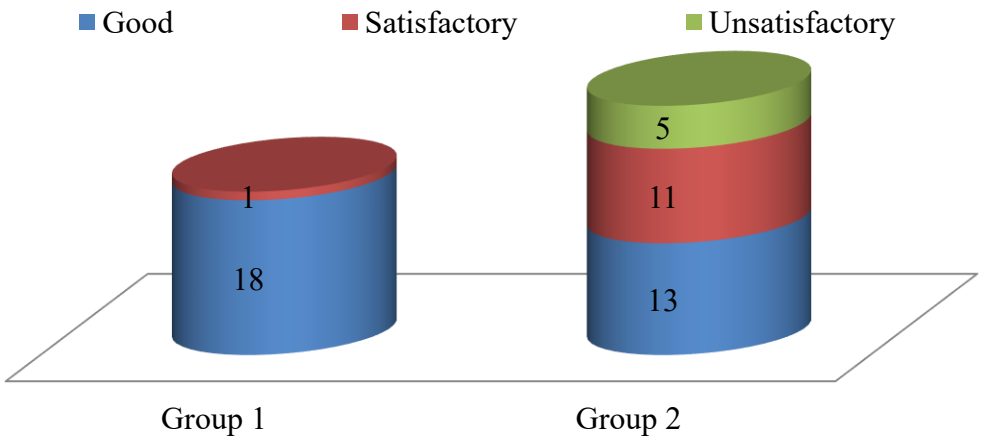

Diagram 4.Indicators for Evaluating Treatment Outcomes in the Late Postoperative Period.

When assessing treatment outcomes in the late postoperative period, changes in indicators were observed compared to the early postoperative period, particularly in the control group. In the main group (n=19), the assessment results remained largely unchanged, with a "good" outcome in 18 patients (94.7%) and a "satisfactory" outcome in 1 patient (5.3%). In the control group (n=29), a "good" outcome was achieved in 13 patients (44.8%), a "satisfactory" outcome in 11 patients (37.9%), and an "unsatisfactory" outcome in 5 patients (17.2%). Notably, 17.2% of patients in the control group had a late postoperative treatment outcome that was not satisfactory.

Therefore, it can be said that clinical observations in the late postoperative period in the main group (n=24) demonstrated a trend toward improvement over the course of the follow-up period. In contrast, the control group (n=36) demonstrated a negative trend, with 3 patients (8.3%) experiencing recurrent vertebral fractures.

V. DISCUSSION

All patients underwent percutaneous vertebroplasty (PVP) of the vertebral bodies, with a total of 130 treated vertebrae. The assessment of patients' conditions in the early and late postoperative periods in

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both groups was conducted using the VDS and Oswestry scales.

In the early postoperative phase, pain syndrome decreased in both groups, as measured by the VDS scale. According to the results, the main group experienced complete regression of pain syndrome more often (95.8%) than the control group (22.2%). Neither group experienced more than two points of pain during the postoperative phase.

In the early postoperative phase, both groups also demonstrated an increase in quality of life as measured by the Oswestry scale. During this time, the main group's quality of life decreased by a maximum of 20%, while the control group's quality of life decreased by 26%. None of the 60 patients who had surgery had an Oswestry index higher than 26 percent. Using the criteria of good, satisfactory, and unsatisfactory results, the primary and control groups' treatment efficacy in the early postoperative period was compared. Compared to just 22.2% of patients in the control group, analysis revealed that 92% of patients in the main group experienced a favorable outcome.

Follow-up information was provided for 48 patients (80% of the total), comprising 19 patients (40%) from the main group and 29 patients (60%) from the control group. The 2018–2024 follow-up phase lasted anywhere from six months to six years.

In the late postoperative period, according to the VDS scale, no significant changes were observed in the first group, whereas the second group showed a negative trend, with pain levels reaching 4 points in 17.3% of cases.

According to the late postoperative Oswestry scale results, 42% of patients in the main group demonstrated a significant improvement in quality of life (ODI <13%), compared to 24% in the control group.

It is important to note that in the main group (n=24), clinical observations in both the early and late postoperative periods showed a consistent trend toward improvement throughout the follow-up period. In contrast, the control group (n=36) exhibited a negative trend, with 3 patients (8.3%) experiencing recurrent vertebral fractures.

VI.CONCLUTIONS

Clinical and neurological manifestations of pathological vertebral body fractures due to osteoporosis are characterized by localized pain syndrome, reaching up to 8 points on the VDS scale. The intensity of pain does not depend on the severity or number of pathological vertebral fractures. Pain syndrome associated with osteoporotic vertebral fractures significantly deteriorates patients' quality of life, with ODI scores reaching up to 86%.

The use of percutaneous vertebroplasty in the treatment of osteoporotic vertebral fractures, with complete restoration of vertebral load-bearing capacity, leads to a significant regression of pain syndrome (95.8%).

In pathologically fractured vertebrae affected by osteoporosis, the use of the developed computer program "Calculating the volume of bone mineral density" helps to reliably determine the volume of bone cement required for injection into the vertebra, thereby fully restoring its support.

A comparative analysis of the results of using unilateral and bilateral approaches in performing percutaneous vertebroplasty in patients with osteoporosis of the vertebral bodies shows that when using a unilateral approach, the amount of bone cement injected does not exceed 4 ml, while with bilateral access it reaches 6 ml or more.

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