MEDWIN PUBLISHERS
Committed to Create Value for Researchers

Journal of Orthopedics & Bone Disorders
ISSN: 2577-297X

# Adaptation of C1 and C2 Vertebral Implants to the Cervical Region

**Logutov Petr D[1] and Pichkhidze Sergey Ya[2]***

[1]Student scientific supervisor, Yuri Gagarin State Technical University of Saratov, Russia

[2]Doctor of Technical Sciences, Yuri Gagarin State Technical University of Saratov, Russia

***Corresponding author:** Pichkhidze Sergey Ya, Saratov State Technical University, Saratov, Russia

**Research Article**

**Volume 10 Issue 4**

**Received Date:** September 22, 2026

**Published Date:** November 26, 2026

DOI: 10.23880/jobd-16000303

## Abstract

This study addresses the implantation of a vertebral implant into the cervical spine using X-ray imaging and 3D modelling. The aim of the research was to evaluate the stress–strain state of the "implant–bone tissue" system under physiological loads. It has been demonstrated that the minimum stress values for loads of 70 ... 200 N remain insignificant. It should be noted that with increasing load, the VT-6 titanium alloy experiences higher stress levels; however, these do not reach critical values. Displacements along the X, Y, and Z axes remain acceptable for all load levels, which indicates the stability of the model and the absence of pathological mobility. The minimum safety factor values under an applied load of 70...200 N ranges from 9.25 to 3.23 units, which confirm the reliability of the structure even under maximum exposure. Thus, the implant demonstrates a sufficient strength margin and resistance to physiological loads of the cervical spine. The obtained results confirm that the selected geometric parameters and implant material ensure the required level of biomechanical compatibility. Overall, the developed model can be employed for further integration of the cervical spine vertebrae of segments C1 and C2, as well as for preoperative planning and optimization of fixation parameters.

**Keywords:** Implant; Bone; Load; Osseointegration

## Introduction

The cervical spine plays a key role in the human body. Its main characteristics include mobility (providing freedom of head movement), blood supply to the brain (vertebral arteries pass through the cervical vertebrae, supplying the posterior regions of the brain), and the connection between the spinal cord and the brain. Due to the complex anatomy and critical functions of this region, any surgical intervention—especially implantation—requires a highly precise and individualized approach.

To create a high-quality and timely implant for a specific patient, modern practice uses 3D modeling. This method allows the development of implants based on input data, such as CT or MRI scans, enabling a patient specific approach. The implant design process is complex, as the engineer must consider many factors, such as selecting a material with mechanical properties similar to bone tissue and ensuring biocompatibility with the patient's body. Critical aspects also include load distribution analysis to match physiological stresses in the cervical region, as well as optimizing the implant's geometry to promote osseointegration and minimize stress shielding.

Additive manufacturing (3D printing) further enhances this workflow by enabling the fabrication of intricate, porous structures that mimic trabecular bone architecture. Such structures not only improve mechanical compatibility but also facilitate tissue ingrowths and long term stability. The integration of topology optimization and biomimetic design strategies allows engineers to balance strength, weight, and biological performance, ultimately supporting safer and more effective spinal reconstruction. In particular, materials



CC BY

like PEEK (polyaryletherketone) and titanium mesh offer distinct advantages: PEEK provides radiolucency and a modulus closer to bone, reducing stress shielding, while titanium supports robust osseointegration due to its surface properties and structural versatility.

This approach holds significant promise for advancing personalized solutions in cervical spine surgery, particularly for challenging cases such as C1-C2 reconstructions, where anatomical precision and biomechanical reliability are paramount. By combining advanced imaging, computational modeling, and additive technologies, clinicians and engineers can tailor implants to individual anatomical variations, improving surgical outcomes and patient recovery [1-7].

**Purpose of the work:** implementation of a vertebral implant into the cervical region using X-ray imaging and 3D modeling.

At the initial stage of implant development, it is necessary to perform an X-ray examination and conduct a detailed analysis of the studied area. The RadiAnt DICOM Viewer software was used for X-ray image analysis. This program allows measurements at real scale and enables a more detailed study of the selected region (Figure 1).

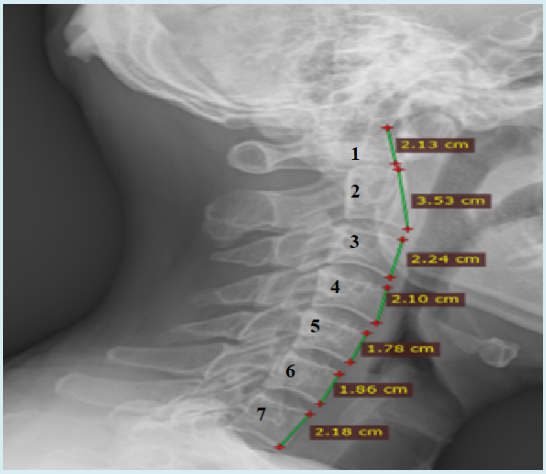


**Figure 1:** Measurement of the dimensions of the cervical vertebrae (side view): 1 – C1 vertebra; 2 – C2 vertebra; 3 – C3 vertebra; 4 – C4 vertebra; 5 – C5 vertebra; 6 – C6 vertebra; 7 – C7 vertebra.

Based on the X-ray image, implants of the cervical vertebrae segments C1 and C2, as well as an intervertebral disc, were developed in SolidWorks 2024 (Figures 2-4).

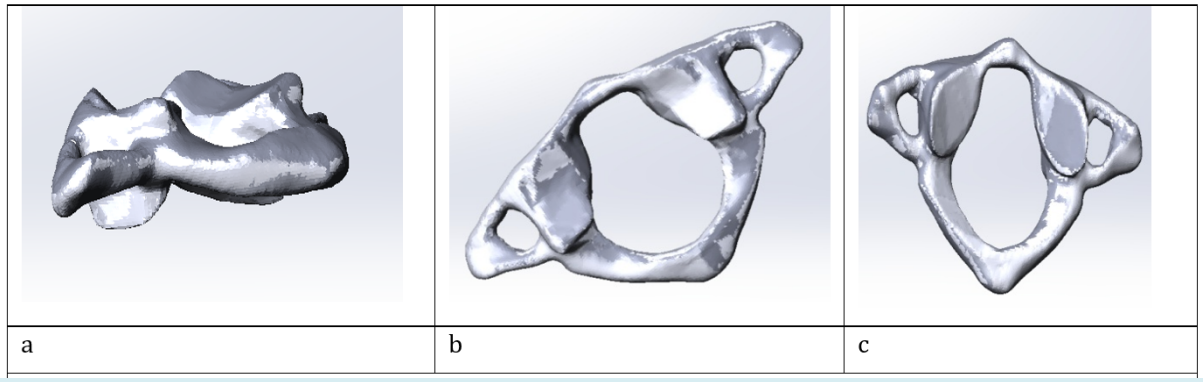


**Figure 2:** C1 cervical vertebra, a - side view, b - top view, c - bottom view.

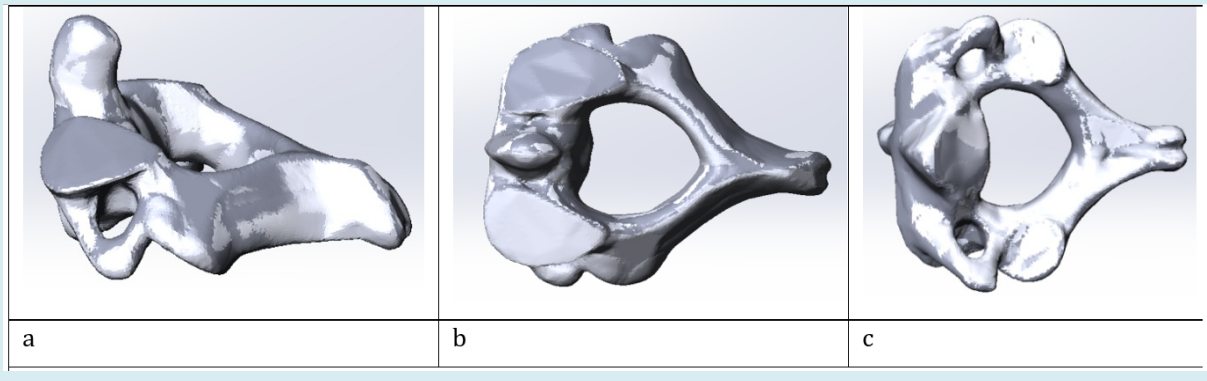


**Figure 3:** C2 cervical vertebra, a - side view, b - top view, c - bottom view.



Copyright© Logutov Petr D and Pichkhidze Sergey Ya.

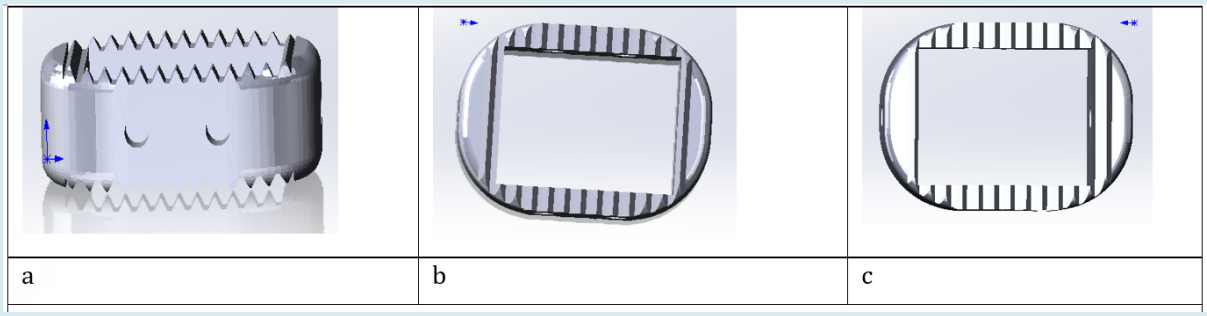

**Figure 4:** Intervertebral disc, a - side view, b - top view, c - bottom view.

An assembly of vertebrae C1 and C2 in conjunction with the intervertebral disc was also created (Figure 5).

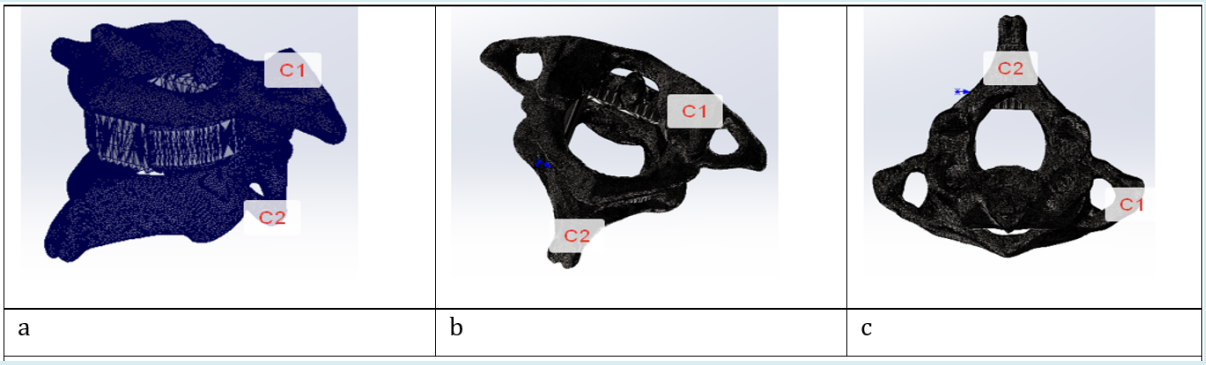


**Figure 5:** Assembly of C1 and C2 vertebrae, a - side view, b - top view, c - bottom view.

Titanium alloy Ti-6Al-4V was selected as the material due to its biocompatibility with the human body. The material has the following technical characteristics (Table 1).

| Features | Meaning | Units of measurement |
|---|---|---|
| Elastic modulus | 1,0480031e^+11 | $N/m^2$ |
| Poisson's ratio | 0,31 | |
| Shear modulus | 4,1023807e^+10 | $N/m^2$ |
| Density | 44,28,784 | $kg/m^3$ |
| Ultimate tensile strength | 1050000000 | $N/m^2$ |
| Yield strength | 827370880 | $N/m^2$ |

**Table 1:** Technical specifications of Ti-6AI-4V titanium material.

Based on the model and technical characteristics, load calculations were performed for the assembled structure, allowing evaluation of the feasibility of implanting two cervical vertebrae simultaneously. The working load range of the model was 70–200 N. Since each person is unique and has a different head weight, it was decided to use a different range of loads (Figure 6).



Copyright© Logutov Petr D and Pichkhidze Sergey Ya.

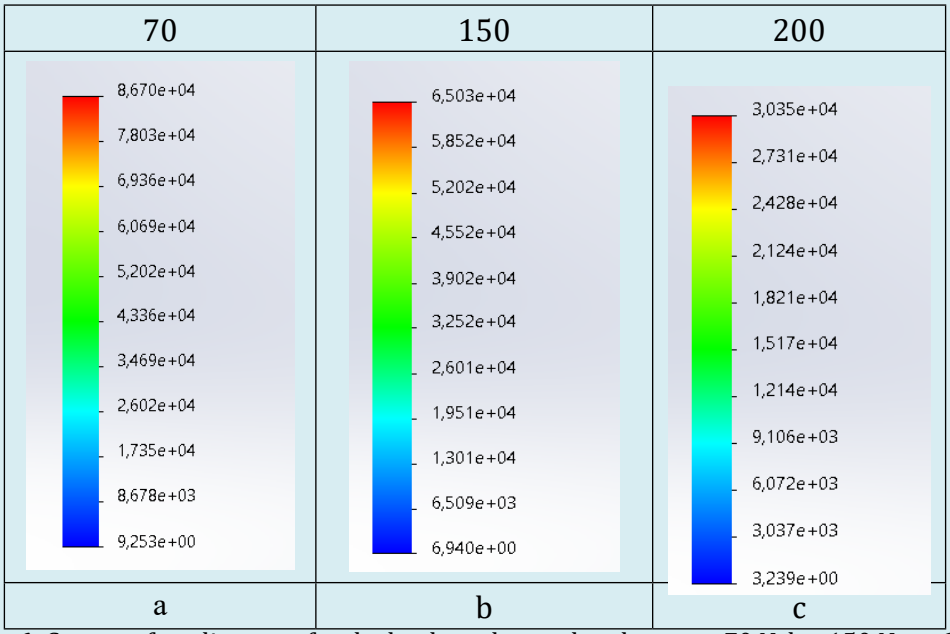


**Figure 6:** Stress safety diagrams for the loads under study, where: a – 70 N, b – 150 N, c – 200 N.

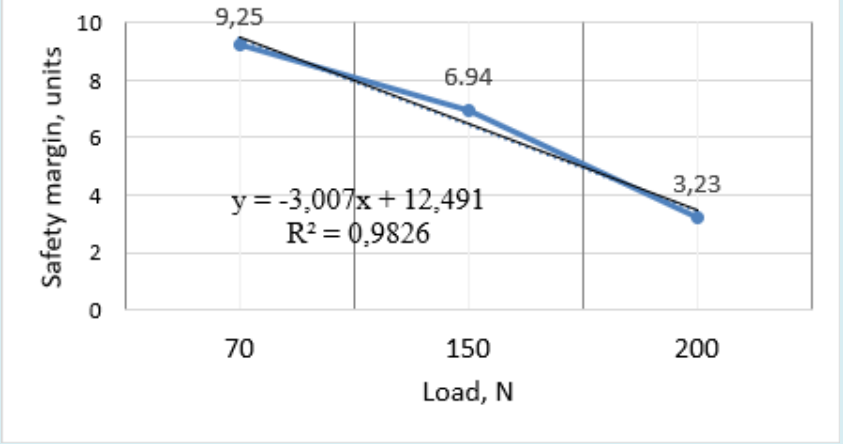


**Figure 7:** Dependence of the safety factor on the load.

The work also used 3D printing of C1, C2 segments of the cervical spine and an intervertebral disc made of PLA plastic (Figures 8-10).



**Figure 8:** 3D model of the cervical vertebra of the C1 segment.



Copyright© Logutov Petr D and Pichkhidze Sergey Ya.



**Figure 9:** 3D model of the cervical vertebra of the C2 segment.

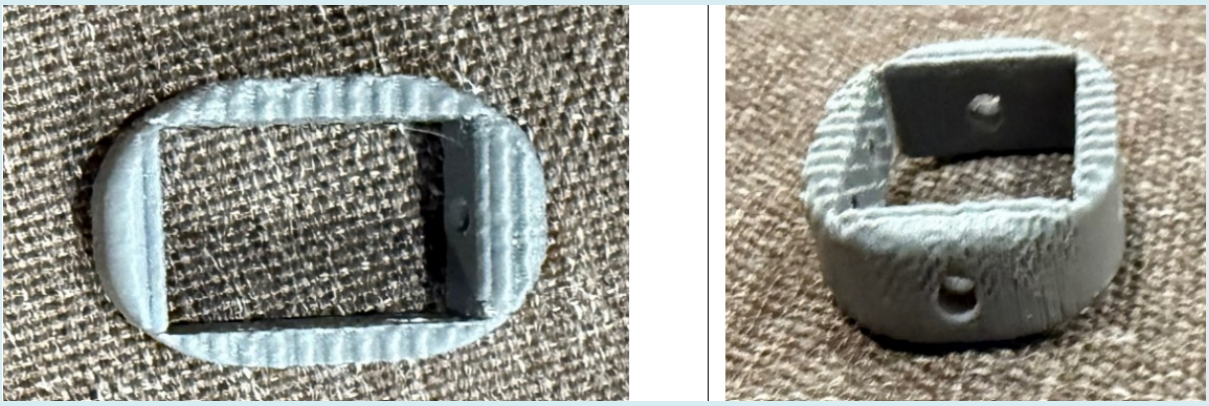

**Figure 10:** Intervertebral disc.

## Conclusion

1. Minimum stress values for loads of 70-200 N remain insignificant;
2. As the load increases, the material experiences higher stress levels;
3. Displacements along the X, Y, and Z axes remain within acceptable limits for all load levels, indicating model stability;
4. The minimum safety factor values under loads of 70–200 N range from 9.25 to 3.23, demonstrating structural reliability.

## Findings

1. Implementation of a vertebral implant into the cervical region using X-ray imaging was carried out.
2. The developed model can be used for further integration of cervical vertebrae segments C1 and C2.

## References


1. Ivanov II, Petrov PP (2021) Modern materials and modeling methods for the development of bone implants. Medical equipment and biomedical materials 3: 45-52.
2. Smirnova AA, Kuznetsov VV (2020) Methods of modeling and optimization of orthopedic implants. Engineering systems and technologies 2: 78-85.
3. Kolesnikova TS, Lebedev M (2019) Biocompatible Materials: Properties and Applications in Osteosynthesis. Journal of Materials Science and Biomedical Technologies 15(4): 112-119.
4. Petukhov Yu K, Grigoriev P (2022) Modern Methods of 3D Modeling for the Development of Implants. Reports of the Russian Scientific Center 7: 33-39.
5. Titova NR, Ivanov VL (2018) X-ray analysis and visualization of the spine for surgical planning. Journal of X-ray Research 36(2): 125-132.
6. Johnson T, Müller R (2019) Finite Element Analysis of Cervical Vertebrae Implants. Journal of Orthopedic Research 37(3): 785-792.
7. Logutov PD (2025) Introduction of the C2 vertebra implant into the cervical region. SMTT-05 Modern Materials, Techniques, and Technologies, Kursk: University Book, pp: 297-300.




Copyright© Logutov Petr D and Pichkhidze Sergey Ya.

## YOUR RESEARCH DESERVES GLOBAL VISIBILITY

• Publish • Discover • Share • Connect

| MEDICAL | CLINICAL | LIFESCIENCES | PHARMA |
|---|---|---|---|
| 90+ OPEN ACCESS JOURNALS | | 400+ RESEARCH TOPICS | |

SUBMIT YOUR RESEARCH
Submit your manuscript through our online submission system.

REPRINTS
If you require a reprint of any article, please contact us.
info@medwinpublishers.com

BECOME A REVIEWER
Share your expertise and contribute to scholarly publishing.

SCAN TO EXPLORE MEDWIN JOURNALS

• Journals • Submit Manuscript • Reviewer Program • Article Tracking

Our Journals indexed in

Embase® ELSEVIER | PubMed National Library of Medicine NLM | Crossref | Google Scholar | INDEX COPERNICUS INTERNATIONAL | ISSN INTERNATIONAL STANDARD SERIAL NUMBER INTERNATIONAL CENTRE | ROAD DIRECTORY OF OPEN ACCESS SCHOLARLY RESOURCES | EuroPub | Scilit | WorldCat® | Academic Resource Index ResearchBib | ADVANCED SCIENCE INDEX | INTERNATIONAL Scientific Indexing | ICMJE INTERNATIONAL COMMITTEE of MEDICAL JOURNAL EDITORS



This article published by Medwin Publishers, 28475 Witherspoon Dr, Novi, MI 48377, United States, +1-248-247-6042, WhatsApp +1 (248) 275-1133, info@medwinpublishers.com



© 2026, by the Authors. The articles published from this journal are distributed to the public under "Creative Commons Attribution License" (https://creativecommons.org/licenses/by/4.0/). Therefore, upon proper citation of the original work, all the articles can be used without any restriction or can be distributed in any medium in any form.