



ODONTOID SCREW FIXATION OF THE C2 VERTEBRA FRACTURES IN CHILDREN AND ADOLESCENTS: INITIAL EXPERIENCE USING THE TECHNIQUE

D.A. Glukhov, T.A. Dzhumatov, A.V. Gubin

Pirogov Clinic of High Medical Technologies at St. Petersburg State University, Saint Petersburg, Russia

Objective. To study the primary outcomes of surgical treatment of C2 odontoid fractures in children using the odontoid screw.

Material and Methods. The data of the anamnesis, physical examination, radiography and CT of the cervical spine of 5 children with a median age of 15 years (min – 5, max – 17) who underwent odontoid screw fixation for a C2 odontoid fracture were analyzed. Own data were compared with literature data.

Results. Four patients were diagnosed with a displaced odontoid fracture, and one developed a pseudoarthrosis despite conservative treatment. No neurological disorders were detected. The patients' primary complaint was neck pain with movement. The median surgical time was 175 minutes with blood loss of 10 ml. No intra- or postoperative complications were recorded. Three months after surgery, pain relief and CT-confirmed consolidation of the odontoid process were noted.

Conclusion. Odontoid screw fixation of the C2 vertebra is suitable for use even in young children. The low complication rate and high percentage of primary consolidation with preserved rotational motion make it the method of choice for treating fractures and post-traumatic pseudoarthrosis of the odontoid process.

Key Words: fracture; odontoid process; C2; axis; surgery; odontoid screw; children; adolescents.

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Cervical spine injuries in children account for up to 1.0–1.6% of cases [1–4], with upper cervical spine injuries comprising 42.0–85.3% of these injuries in children aged under 8 [1, 2, 5, 6]. This high prevalence of injuries is attributed to age-related anatomical features: a larger head-to-body proportion, weak cervical musculature, and the presence of a synchondrosis between the base of the odontoid process and the C2 vertebral body, which represents an embryonic remnant of the C1–C2 intervertebral disc [7]. Ossification of this synchondrosis occurs across a wide age range, spanning from 3 to 9 years [8–11], although the central segment of the synchondrosis persists throughout life in some individuals [9, 12]. Considering the incidence and age-specific characteristics, a classification system for C2 synchondrosis injuries in children has been presented, whereas the Anderson and D'Alonzo classification of odontoid fractures [13] is commonly utilized for adult patients and pediatric cases following synchondrosis

ossification. In older children and adolescents, odontoid fractures occur, as in adults, most frequently as a result of high-energy trauma (motor vehicle accidents, falls from height) or sports-related injuries [1, 2, 5, 6].

Non-displaced odontoid fractures can be managed conservatively using rigid external immobilization, such as a Philadelphia collar. In cases of displacement, four surgical treatment methods are utilized: halo-vest immobilization, Goel–Harms C1–C2 fixation [14, 15], Magerl C1–C2 transarticular fixation [16], and odontoid fixation with partially threaded cannulated screw [17]. Among the presented surgical techniques, only odontoid screw fixation preserves rotational motion in the C1–C2 segment without requiring implant removal. Despite this, the technique has not gained widespread adoption among pediatric spinal surgeons.

The purpose of this study is to evaluate the early outcomes of surgical management for C2 odontoid fractures in children using odontoid screw fixation.

Material and Methods

Study design: A single-center retrospective cohort study.

Inclusion criteria:

- displaced type II odontoid fracture (according to Anderson and D'Alonzo classification) of the C2 vertebra secondary to trauma.
- pseudoarthrosis formation during conservative management;
- treatment method – odontoid screw fixation; and
- age at surgery under 18 years.

Exclusion criteria:

- non-displaced fractures managed conservatively;
- pathological fractures secondary to destructive bone lesions; and
- congenital anomalies of the C2 vertebra (odontoidium).

All patients underwent history taking, physical examination, and lateral and open-mouth views of cervical spine radiography both pre- and postoperatively. Additionally, cervical CT was performed before surgery to delineate fracture char-

acteristics, postoperatively to evaluate screw placement, and at 3 months to assess bone consolidation.

Data are presented as Me (Q1–Q3 interquartile range) because the distribution deviated from normality. Data collection, management, and organization were performed using the LibreOffice Calc spreadsheet editor (version 25.8.2, MPL v.2).

In accordance with the inclusion and exclusion criteria, the study group comprised data from five patients with a median age of 15 years (min 5, max 17) who underwent surgery for C2 dens fractures between 2024 and 2025 (Table).

Operative technique

In cases of odontoid process displacement into the vertebral canal, flexible bronchoscopy-guided intubation was performed to prevent further dislocation. One patient had a tracheostomy secondary to a traumatic brain injury (TBI) and prolonged mechanical ventilation.

Under general anesthesia, the patient's head was secured in a halo ring using pins at the frontal and parietal eminences. Under fluoroscopic guidance (C-arm), reduction of the odontoid process fragment was performed. If necessary, digital pressure was applied transorally. The head was immobilized in the corrected position.

For the spinal fusion, the patient stayed in the supine position with a bolster under the shoulders. The mouth was fixed open using a radiolucent mouth gag to allow unhindered fluoroscopic control. At the C4–C5 vertebral level on the right side (accounting for the surgeon's right-handedness), a horizontal

skin incision up to 15 mm in length was made medially to the anterior border of the sternocleidomastoid muscle, and a channel was bluntly created up to the base of the C2 vertebra. Subsequently, under fluoroscopic control (C-arm guidance) and using a tubular protector, a K-wire was advanced along the midline through the anteroinferior corner of the C2 vertebral body up to the apex of the dens, with the fracture in a reduced position. Over the guide pin, the bone tunnel was reamed using a 3.2 mm cannulated drill bit, and the fracture site was fixed with a 4.5 mm partially threaded cannulated screw. During the procedure, particular care was taken not to advance the pin into the foramen magnum and to avoid its premature removal. Intraoperative CT was performed in all patients. Following osteosynthesis, the patient's head was rotated under fluoroscopy to confirm fixation stability. The wound was closed in layers without drains.

Results

Within this cohort, four patients were diagnosed with a displaced odontoid fracture resulting from acute trauma (Figs. 1, 2), while one patient developed a nonunion following continuous immobilization in a Philadelphia collar for 1 year and 5 months (Fig. 3).

No trauma-related neurological deficits were identified. The primary complaint of all patients upon admission was motion-induced neck pain, scoring 5 (5–6) on the VAS.

The median operative time was 175 (100–175) min, and the blood loss was

10 (5–20) mL. The intraoperative and postoperative courses were uneventful.

All patients were verticalized on the day of surgery. A soft cervical collar was prescribed for 4 weeks. Post-immobilization, gradual rotational range-of-motion (ROM) exercises of the cervical spine were initiated.

Short-term outcomes were evaluated in four patients; Patient 4 was lost to follow-up. At 3-month post-op CT, patients demonstrated consolidation of the odontoid process. Pain relief achieved.

Discussion

The majority of publications in electronic databases report isolated clinical cases of odontoid fractures in children treated with odontoid screw fixation [18–25].

Farrokhi et al. [25] reported a highly noteworthy case of an 18-month-old girl who underwent surgical treatment with a 6-year follow-up. Serial radiographs demonstrate stable C1–C2 alignment with intact implant positioning and no evidence of secondary deformity despite patient growth.

Three studies [26–28] present clinical series of 3, 4, and 13 patients, respectively. The largest series represents a 10-year single-center experience by Sawarkar et al., with a follow-up period ranging from 20 to 72 months. Analyzing the treatment outcomes, the investigators noted complete consolidation in 10 cases, fibrous union in one case, and nonunion in one case. One patient died from neurovascular complications during migration of a K-wire into the foramen magnum.

Table

Clinical characteristics of patients with odontoid fractures (C2 dens fractures)

Patient	Age, years	Gender	Time elapsed since injury	Nature of injury	Type of fracture	Displacement/Pseudarthrosis	Consolidation at 3 months
1	15	M	10 days	Bicycle accident	2	Backward	+
2	5	M	34 days	Pedestrian motor vehicle accident	2	Forward	+
3	11	M	1 year 5 months	Blunt force trauma from a swing	2	Pseudarthrosis	+
4	17	M	33 days	Fall from height	2	Backward	No available
5	17	F	14 days	Pedestrian motor vehicle accident	2	Rightward	+

Several published studies have also utilized CT of the craniovertebral junction to evaluate the anatomical characteristics of the odontoid process in pediatric populations. Specifically, Lin et al. [29] demonstrated sex-based differences in permissible screw length and odontoid process diameter. Additionally, a process diameter of ≥ 4 mm is present in over 90% of pediatric patients aged 7–18 years and in 57% of patients aged 2–6 years, which permits the utilization of a standard 3.5-mm screw. Other investigators also confirm sex differences in the length and diameter of the odontoid process [30–

32]. Dou et al. [31] recommend using 2.5–3.0 mm screws for children aged 3–5 years, 3.0–3.5 mm screws for those aged 6–9 years, and 3.5 mm screws for those aged 10–14 years; they also conclude that the dual-screw construct is not feasible in the pediatric population. Concurrently, Štulík et al. [32] reported the theoretical feasibility of inserting two 3.5 mm screws in children over one year of age.

The literature cited above demonstrates that the screw insertion angles relative to the lower vertebral endplate decreases by adolescence and shows no gender dependence [29–33].

Biomechanical cadaveric studies revealed no significant differences in stability between single- and dual-screw fixation [34, 35]. This allows for single-screw fixation in pediatric patients with a small odontoid process.

Comparing open odontoid screw fixation with the percutaneous technique in adults, Wang et al. [36] reported a shorter operative time and lower blood loss for the minimally invasive approach, with a comparable radiation exposure. In the pediatric population, Dou et al. [37] analyzed a large radiological dataset and discouraged the percutaneous approach in children

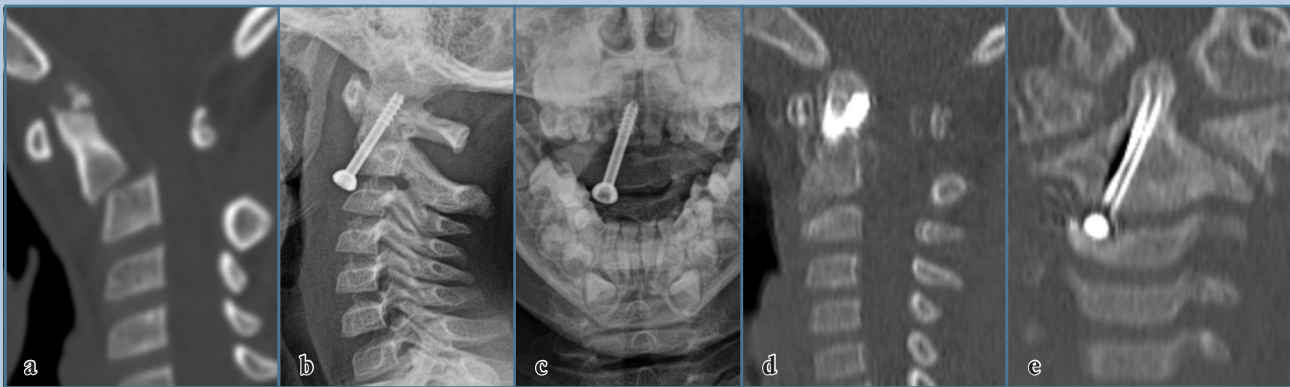


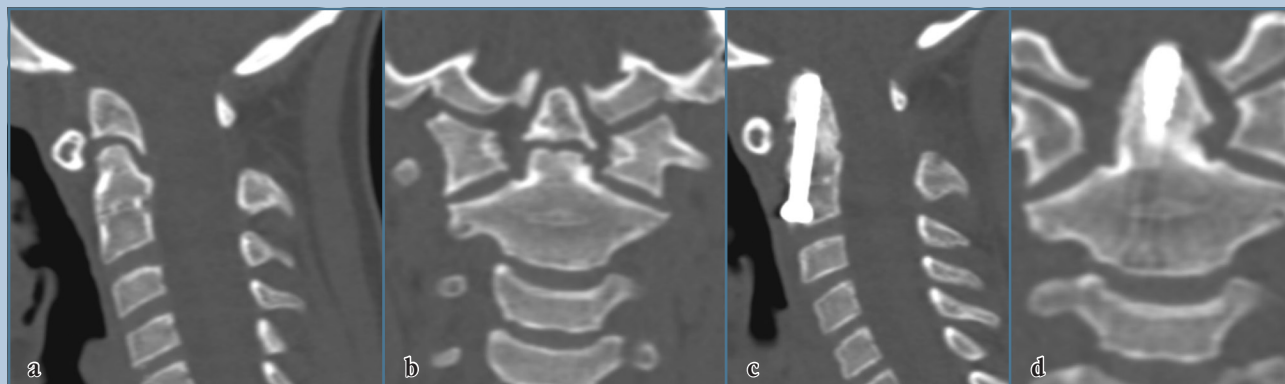
Fig. 1

Patient 2: **a** – sagittal CT slice showing anteriorly displaced fracture – separation of the odontoid physis (odontoid epiphyseolysis); **b, c** – postoperative biplanar cervical spine radiographs; **d, e** – sagittal and coronal CT slices at 3-month follow-up



Fig. 2

Patient 5: **a, b** – preoperative coronal and sagittal CT slices: displaced odontoid fracture with rightward translation. **c, d** – postoperative frontal and sagittal CT slices

**Fig. 3**

Patient 3: (a, b) sagittal and coronal CT slices at 1 year and 5 months post-injury demonstrating a post-traumatic odontoid process nonunion; (c, d) sagittal and coronal CT slices at 3 months postoperatively

under 6 years old, whereas it remains an option for older patients subject to rigorous CT data analysis.

Prabhat et al. [38] conducted a systematic literature review on pediatric odontoid fractures to establish a management algorithm for selecting between conservative and surgical interventions.

Conclusion

Our clinical experience with odontoid screw fixation of the C2 vertebra fractures, corroborated by literature data, demonstrates the feasibility of this technique even in early childhood. The low complication rate and high rate of pri-

mary union, while preserving rotational motion, allow the technique to be considered an alternative to prolonged external fixation, as well as the method of choice for the treatment of symptomatic pseudarthrosis (or nonunion) of the odontoid process.

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Authors' Info

✉ Dmitrii Aleksandrovich Glukhov, MD, Cand. Sci. (Medicine); 13–15 Kadetskaya line V.O., Saint Petersburg, 199004, Russia; eLibrary SPIN: 3376-2569; ORCID: 0000-0002-6880-8562; dmitriy.a.glukhov@gmail.com

Timur Alisherovich Dzhumatov; eLibrary SPIN: 5078-0739; ORCID: 0000-0001-6892-9076; shmiga96@mail.ru

Alexander Vadimovich Gubin, MD, Dr. Sci. (Medicine), Professor; eLibrary SPIN: 2014-6518; ORCID: 0000-0003-3234-8936; shugu19@gubin.spb.ru

