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REVIEW

Classifications for the odontoid fracture: The significance and application of the "Korres classification"

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ABSTRACT

Purpose: Our intention with this article is to review current literature concerning the classification of the fractures of the odontoid process and present their treatment concerning classification with special emphasis to the Korres classification that we routinely use. In addition we intend to review and summarize the classification significance and compare their usefulness with one another.

Methods: We conducted an extensive search in the literature using PubMed, Web of Science and Google Scholar and used in our study the most important of such articles.

Results: Fractures of the odontoid process represent a particular entity; they need a careful handling as their behavior is not easily predictable. Diagnosis of the correct type of fracture is very important. Complications due to multiple factors, are usual and have to be carefully managed. Pseudarthrosis is the most common complication related to many factors the most important being instability.

Conclusions: The Korres classification has been proven successful and is now considered more realistic as it is simple, it includes the whole spectrum of fractures, it refers to one single anatomical structure, it correlates to the biomechanics of the axis, it indicates the prognosis and it suggests the management of the fracture. The study of cases by Korres et al. revealed some directions for the development and treatment of these fractures. It is showed that type A and D fractures can and should be treated conservatively; they usually have a good prognosis. Type B fractures are prone to further complications and hence should be treated – in their majority - surgically. Type C fractures need to be followed closely and in case of instability and/or late displacement have to be operated.

KEY WORDS: odontoid process fracture; classification; review; treatment choice; cervical spine

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Introduction

Fractures of the odontoid process are not rare and they represent an individual entity. The interest these fractures are linked to is first, the fact that they involve an anatomic element which is developed in a very important area of the skeleton, in close relationship to vital structures and second, the multiple pattern of fracture this anatomic element can sustain. A third interesting point is the physical history and the management of these fractures which is closely related to the type of the lesion.

The incidence of these fractures is around 14% [1] among the cervical spine fractures and may occur at any age, with a higher risk for patients older than 65 years old. Nevertheless it is important to clarify that in this age group the fracture of the odontoid is more likely to be missed at the initial examination.

The main causes of injury is a road traffic accident or a fall, but, other causes are, also, implicated to these injuries concerning high energy trauma. However, the exact prevalence is not known as a certain number of patients who sustained such an injury do not survive and are dead in the time of arrival to the hospital. The fracture of the odontoid is often caused by high-energy trauma with the implication of a combination of forces and the major loading path that cause the lesion is not well established. According to experimental data the causes of the fractures of the odontoid process are a combination of vertical compression and horizontal shear which, acting in a different angle, create different patterns of fracture. In practice we can assume that the main forces responsible for a fracture of the odontoid process are the hyperextension, the flexion and the lateral bending, but it is certain that combined forces could also be responsible for a fractured odontoid.

The purpose of this study is to review current literature concerning the classification of odontoid fractures and the contribution of the existing classifications to clinical decision making for treating such fractures. Furthermore, we intend to expose several advantages of the Korres classification that we prefer to use.

Diagnosis

The clinical presentation of this injury varies from a mild to a severe one (quadriplegia or even death). [1] Patient sometimes present in the emergencies department holding their head or they are transferred on a stretcher complaining of pain in the cervical region; they usually keep their head still unable to move it because of the pain. A thorough clinical examination to exclude the symptoms corresponding to a neurological damage is mandatory although these are usually missing. The severity of the neurological disorder correspond to the degree of displacement and the consequent instability of the odontoid process. Older people have a higher rate of mortality [1].

In addition, it is important to look for an involvement of the vertebral arteries which, if damaged, could induce symptoms not only at an early stage, but, also, several days after the accident. The fracture of the odontoid process represents a separate entity and special attention is needed in order to recognize the fracture, but also, to apply the appropriated treatment protocol. Nowadays, it is clear that the pattern of the fracture contributes in favor of poor prognosis, that is, in the occurrence of complications, and of pseudarthrosis in particular; at the same time, it may indicates the way these lesions could be managed. So, there is a necessity for a complete and precise clinical and radiological approach, which will permit us to put the correct diagnosis. Problems could arise in children (the presence of congenital malformations, the immature skeleton etc.) and in old people (degenerative disease, pathological condition like tumors etc.). Radiological investigation is of importance. This must include apart the conventional x-ray views [Anterolateral (open mouth view), lateral and in certain instances dynamic views], and also, CT-scan (with reconstruction imaging), MRI and in certain instances 3-D imaging. Of course this will be done in a 'step by step' manner. If the patient is unconscious, then, the entire spine has to be investigated. The raison for such a meticulous radiologic investigation is due to the fact that the fracture pattern is unforeseen, and as multiple forces can be applied to the entire spine, simultaneously or in continuity, fractures at different levels of the spine may be present.

Classification

Two basic classification categories are proposed according to: **a**. the position of the fracture and **b**. to the direc-

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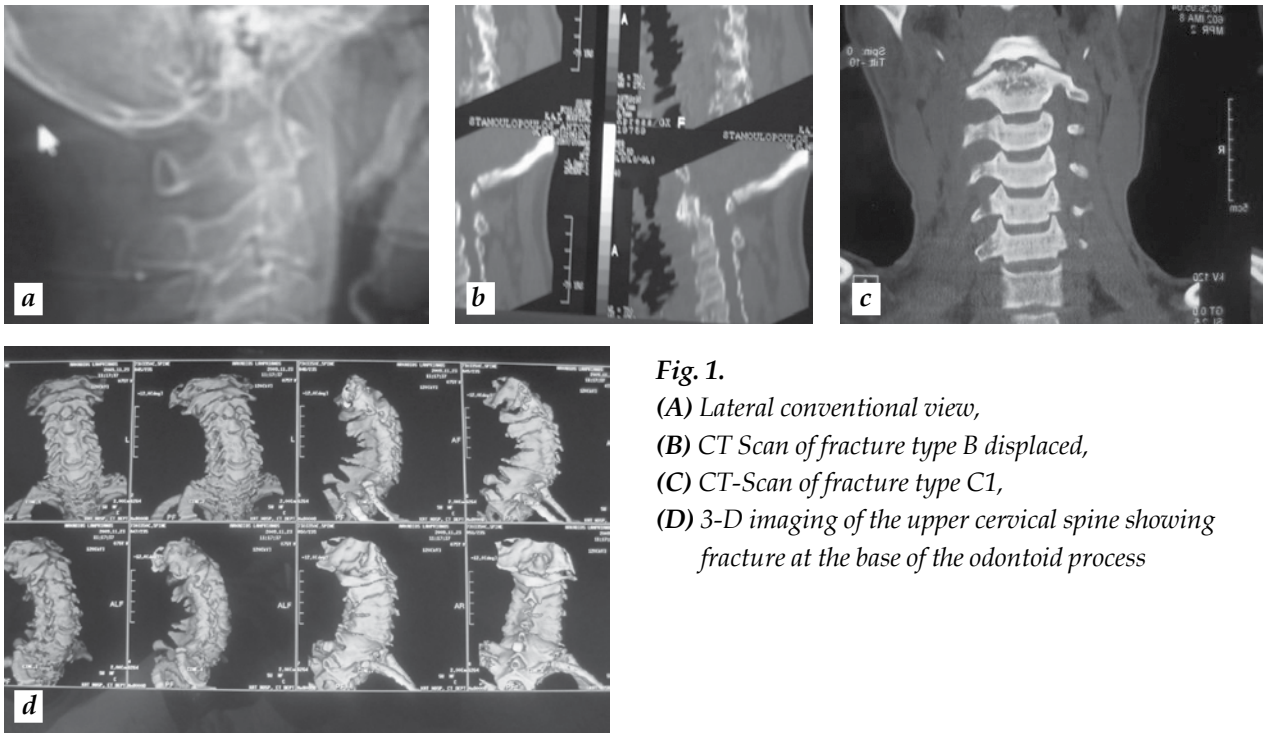

Fig. 1.
(A) *Lateral conventional view,*
(B) *CT Scan of fracture type B displaced,*
(C) *CT-Scan of fracture type C1,*
(D) *3-D imaging of the upper cervical spine showing fracture at the base of the odontoid process*

tion of the fracture line. In the first category there are four different classifications described: (a) The Schatzker classification [2], (b) The Mourgues Classification [3], (c) The Anderson-D'Alonzo classification [4], (d) The Althoof classification [5].

The second category, in which the direction of the line is considered, includes the classification of Roy-Camille [6] with three types of fractures: Anterior oblique, posterior oblique and horizontal.

The evolution in the diagnostic methods revealed the existence of other types of fractures like the vertical one, and the complex fractures. The vertical fracture is characterized by the division of the odontoid process into two parts with the line fracture extending from the apex to the base (**Fig 2e**), while the complex fractures are characterized by a diversity of fracture lines creating the compound or double level fractures.

The fractures of the odontoid process represent the mechanical failure of this particular anatomic element following the application of force [1]. The direction of these forces, the internal architecture, the mechanical strength of the bone trabeculae, the proportion of the cortical and cancellous bone, the magnitude of the odontoid process displacement, the vascular supply of the odontoid process and the age of the patients are the most important factors in the creation of specific fracture types and the prognosis of these injuries. In line, but not, well-documented in the literature, radiographic, and histomorphometry studies outline the structural difference between the odontoid process and the body of the axis. Data from these studies could distinguish the fractures at the base of the odontoid process and the underlying body of the axis. This was also revealed in a recent study using peripheral quantitative computed tomography (pQCT) in cadaveric specimens of the axis [7]. Moreover, this study showed the difference of the internal architecture of the axis between young and older patients; in subjects more than 40-year-old a large void of thin trabecular bone has been identified extending from anterior-inferior to superior- posterior to the base of the odontoid process indicating a mechanically weak region that may predispose to specific fracture patterns [7]. The classification proposed by Anderson-D'Alonzo offers a simple and topographic approach to odontoid process fractures. However, it does not contribute to the thorough understanding of the mechanism of the fracture, nor it incorporates any biomechanical characteristics or specific characteristics of

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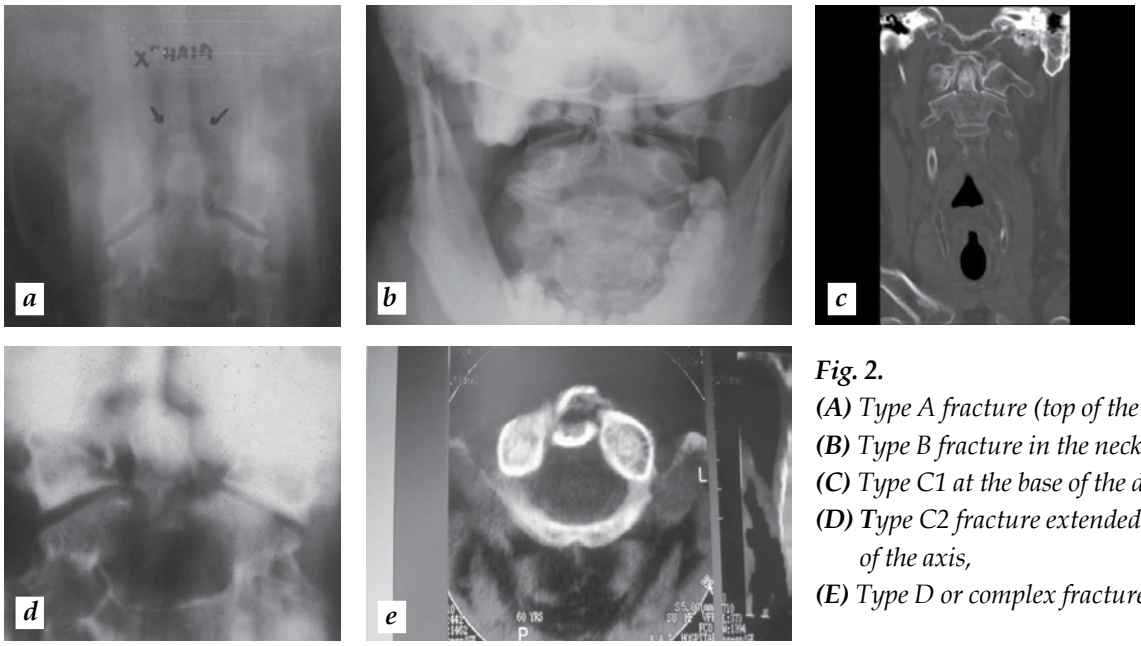

Fig. 2.
(A) *Type A fracture (top of the dens),*
(B) *Type B fracture in the neck of the dens,*
(C) *Type C1 at the base of the dens,*
(D) ***T****ype C2 fracture extended to the body of the axis,*
(E) *Type D or complex fracture*

the internal architecture of the odontoid process and it also has certain limitations. In addition, all the attempts made for its improvement or replacement, the existence of alternative classifications based on the direction of the fracture line, the heterogeneity of the reported pseudarthrosis rates at type II fractures and the presence of various unclassified fracture types such as some vertical or oblique fractures may suggest the inadequacy of the aforementioned classification schemes. The Anderson-D'Alonzo classification is misleading and contributes to confusion regarding fracture location as type III fracture is not a fracture of the odontoid process, but rather a horizontal rostral fracture through the upper aspect of the body of the axis [8]. Further addition of subtypes, such as type IIA [9], type IIB [10], type IIC, type II 1-5 [11] and type IIIA [12] perpetuate the confusion. At the same time, Koller stressed the point of a lack of comprehensive classification for fractures of the body and the odontoid process [13].

The Korres Classification

In the literature there are fractures not corresponding to the already existing classifications and there is an evident confusion, so, it is clear that a more appropriate one would be obligatory [14]. The Korres classification is based on the structural, anatomical and biomechanical properties of the odontoid process [7] and it is an anatomy-based one recognizing four types of fracture pattern, all involving the odontoid process; it also recognizes a zone where practically no fractures are noted (the neutral zone), which is found at the level of transverse ligament, an area of phylogenetically strong bone.

Type A fractures are rare. It is an avulsion fracture at the points of insertion of the alars or apical ligaments with an incidence of 2,3% [1]; Their stability is questionable, but they responded favorable to a conservative treatment.

Type B fractures represent the most common fracture of the dens in the literature, and particularly in the elderly population although they are second in incidence with 44,1% [1]. They are the result of lateral force which initiates a rotational movement. In the presence of osteoarthritic changes this leads easier to a type B or C fracture seeing most frequently in older people. These fractures represent unstable lesions with a tendency to pseudarthrosis, so they need a careful evaluation and appropriate treatment, conservative or surgical, particularly in the old patients.

Type C fractures were found to represent 46,6% [1];

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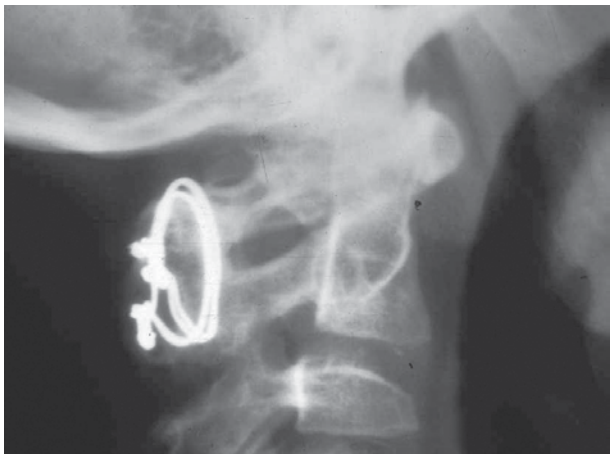

***Fig. 3**. Posterior fusion*

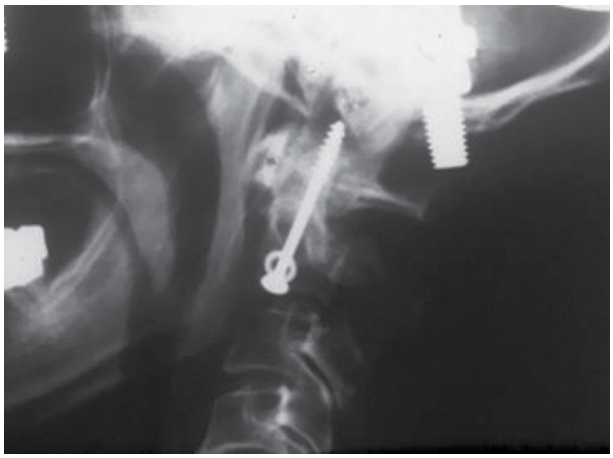

***Fig. 4**. Anterior osteosynthesis*

they have a more favorable outcome than type B, responding to a less aggressive management. Notable is the easiness to recognize a type B from a type C fracture in the lateral view. In type B fracture the Harris ring is intact as the fracture line is above this ring. In type C the fracture line is projected at the upper part of the Harris ring [15].

Type D fractures are not so uncommon (7 % found by Korres, et al. [1]). The axial loading, while the neck is in extension, as well as, a combination of applied forces, which act either simultaneously or not, are probably responsible for this injury. Although it is an unstable lesion, it seems to respond better to a non-surgical treatment.

This classification is considered more realistic since it is simple, it includes the whole spectrum of fractures, it refers only to one anatomical structure (the odontoid process), it correlates to the bio-mechanical characteristics of the axis, it indicates the prognosis of the different fracture types and it provides one with an adequate evaluation and management of these fractures. Fractures not involving the odontoid process, like the type III in the Anderson-D'Alonzo classification, could not be called odontoid fractures but rather fractures of the axis' body in terms of topographic anatomy.

Treatment

Nonsurgical

Fractures of the odontoid process should be divided into (a) stable and (b) unstable [6]; this is necessary in order to proceed with an efficient therapeutic plan. Stable injuries are managed conservatively, while unstable injuries are treated surgically. Fracture's instability depends mostly on the presence of associated lesions, the type of fracture and the initial displacement, particularly if there is vertical displacement.

Type A fractures are treated conservatively by using external mobilization, like a rigid cervical collar or a halo vest; rarely an operation should be required.

In type B fractures, although there are unstable, a controversy is still ongoing among different authors regarding the surgical approach and management of such lesions [16]. An initial conservative treatment should be attempted unless a score of more than 10 points is found [17].

In type C, either conservative or operative management is applied in relation to the instability these injuries present with.

In type D, the appropriate conservative management is offering excellent results. Several treatment modalities are proposed in the presence of this injury, but, before taking any decision, it is prudent, particularly in the elderly, to look for any clinical comorbidities that may affect the management, and to rule out any concomitant or double level fracture of the cervical spine.

Conservative treatment is suggested by the use of traction with the application of a Crutchfield skull tong, in order to reduce and stabilize the fracture or with the

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use of external immobilization like custom-made orthoses, halo vest or cervical collar. In case of application of traction, the weight applied should not exceed 2-3 kg, in order to avoid distraction of the fractured fragments. Special care must be given, not only to the application of traction, but, also, in its direction. Attention must be paid when traction in flexion is applied, because of the potential danger of a vertebral artery lesion or of a neurological injury which may induce respiratory compromise or other neurological conditions.

Stabilization must be kept for at least 4 to 6 weeks during which radiographic control of the position of the fracture is necessary, as well as careful examination for avoidance of complications related to the traction and prolonged bed rest. After this period the patient may be mobilized using a four-point support brace for a period of four to six more weeks. At the end of 10 to 12 weeks, dynamic x-ray views in flexion and extension are taken in order to detect any sign of instability. If instability is proven, then, surgical treatment must be considered. If no instability is detected and the fusion is complete, the patient must use a soft collar for a short period of time.

The use of a Halo vest is not always recommended as the rate of complication reported is as high as 26% with older patients suffering from severe discomfort. Even more, the traction obtained at the beginning, is slowly turned into compression, in the mobilized patient, resulting in malunion, if the reduction of the fracture has been lost due to sliding.

The fusion rate in the conservatively treated patients is reported to be from 35% as high as 85%, but this is related to their age and other parameters, like the time the treatment was applied, the type of the fracture and the initial displacement; the latter is correlated to the direction (anterior or posterior) the fracture is displaced towards. In addition, the traction applied leads sometimes to distraction of the fracture site; this leads to the development of late instability and pseudarthrosis.

Vieweg and Schultheib [18], in contrast to Wolter and Reimann [19], advocate the use of Halo vest in type II fractures, as the percentage of healing is as high as 85%, particularly in the non-displaced ones; they conclude, also, that in type III fractures, the application of a Halo vest is the treatment of choice as the healing rate is about 97%.

The fractures of the odontoid process are prone to complications either at the trauma scene or later in the hospital. Two of the complications appearing in a later period are very significant and have to be well clarified: pseudarthrosis and malunion. Most important is the pseudarthrosis these fractures may develop and the potential danger for late myelopathy or for direct injury of the spinal cord. According to the literature the percentage of pseudarthrosis related to the applied treatment, is 4% to 100 % for all types of fractures and consequently complicating their treatment. The predisposing factors which have been accused for pseudarthrosis include age, mechanism of injury, displacement, the blood supply of the odontoid process, the direction of the fracture line and the type of fracture. Also, the application of excessive traction, the stability of immobilization, the timing of immobilization, as well as the co-existence of another fracture, either in the atlas or even in the axis itself, should be considered carefully. The internal architecture of the axis seems to play an important role in the development of pseudarthrosis. Finally, the possibility of interference of the transverse ligament between the fragments may, also, cause difficulties in the reduction of the fracture, resulting in the development of pseudarthrosis.

Some authors may disagree as to the importance of some of the above factors. To our experience all the above mentioned factors play a certain role and contribute to the development of pseudarthrosis resulting in instability at the fracture site.

Age is an important factor towards pseudarthrosis since it has been proved that nonunion or pseudarthrosis is found at a higher incidence in patients over the age of 50 years. Fracture displacement according to Blokey and Purser [20] should not be correlated to pseudarthrosis. However, other authors did not accept this opinion. Appuzo et al. [21] described that an evident displacement of more than 4 mm should be considered predesposing to pseudarthrosis.

However, it is extremely difficult to be aware of the original displacement that was present at the time of the accident. The traction applied, as well as its direction, plays a significant role according to Ryan and

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Taylor [22]. This is due to the possibility of creating a greater wedging at the fracture level than the one acceptable, and to lead to a deformed odontoid process.

The type of fracture is also implicated in the development of pseudarthrosis since in fractures involving the neck of the dens as well as the direction of the fracture line this was in a rate of 32% and as high as 90%. In our experience the types A, C and D are prone to unite, while type B fracture have a high rate of pseudarthrosis, particularly the one that shown a posterior displacement of more than 5 mm or an angulation of more than 10 degrees.

There is no doubt that the presence of co-existing injuries, as well as a delay in the diagnosis or if the immobilization is not the proper one, then this will increase the instability of the fracture. The knowledge of these parameters as factors influencing the development of a pseudarthrosis, obliged us to proceed in their grading, according to the role each one plays. In this manner, the evaluation of a fracture is easier, as we will predict the risk for pseudarthrosis. It has been estimated that if the sum of the graded factors is greater than 10 points, then the fracture must be characterized as being at risk of pseudarthrosis and surgical treatment must be considered [1, 22].

The blood supply of the odontoid process is not considered to participate in the development of pseudarthrosis. Although a recent experimental study of ours revealed decreased blood supply at the area where type B fractures happen, which is the area where pseudarthrosis often develop [23]. Pseudarthrosis in the elderly is not always a major problem as it was proven; this is not accompanied always by a clinically significant instability due to the development of fibrous tissue at the fracture site. However operation has to be considered if instability persists or if signs of myelopathy are present.

Operative treatment of dens non-unions is not without risk, taking into consideration the age of the patients the high comorbidity those patients have and, also, knowing that the success rate is low.

The second most frequent and severe complication of the fractures of the odontoid process concerns their malunion [1]. Special care so must be given to this complication as may result in spinal canal stenosis which may induce, in long term, cervical myelopathy.

The greater the displacement and wedging of the fracture, the less the width of the spinal canal. This results in chronic compression or friction of the dura matter and the spinal cord on the upper posterior corner of the body of the axis and hence cervical myelopathy. The treatment of this complication is difficult. It requires anterior or posterior decompression combined with posterior fusion extending from the occipital bone to C1, C2 or C3 and even lower.

A number of minor complications may accompany a fractured odontoid. Stiffness, decreased range of motion, discomfort or even mild pain are easily managed with physiotherapy or other conservative methods. Younger patients respond better and an acceptable outcome is usually achieved.

Surgical treatment

Failure to treat conservatively a fractured odontoid is an indication for surgical intervention. Instability must be treated operatively as soon as possible. The operative treatment is suggested by many authors. There are several methods that allow the safe management of the unstable fractures. This is done by closed or open reduction, the use of osseous graft, and stabilization by means of a wire or nylon or use of metallic implant(s). Auto-graft is the most suitable material to be used for achievement of a stable fusion. The approach used is either anterior, lateral, posterior or combined.

Posterior stabilization includes:

Posterior C1-C2 wiring technique with Gallie's or Brooks' techniques [24] or other methods (**Fig 3**).

Anterior stabilization includes:

a. Application of a plate between the anterior arch of the atlas and the body of the axis or the vertebral body of C3.

b. Internal fixation with screw(s). This technique is gaining popularity, but indications have to be set very carefully as osteoporosis, fracture of the anterior wall of the body of C2, posterior displacement, comminuted or type D fractures or even a narrow diameter of the spinal canal are among the contraindications. The

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use of one or two screws depends on thw anatomical characteristics of the odontoid process [25] The osteosynthesis of the odontoid process permits a nearly normal function of the C1-C2 level [26] (**Fig 4**).

Lateral stabilization includes:
Fusion using the Dutoit technique. The lateral approach is used for a C1- C2 arthrodesis in case of traumatic instability, tumors or infections and for cases in which another exposure had been used previously, or a counterindication is present [27].

The surgical results seems to be better than these achieved with a non-operative management as the reported fusion rate is high between 80-100%. However, there is not unanimous acceptance of an appropriate treatment for patients with these fractures, particularly in the elderly population. (**Table I** summarizes the indications for the appropriated management of an odontoid fracture). Physiotherapy in both instances, has an important role to play in the final outcome those patients should have.

We can easily appreciate the importance of dens fractures; they need correct diagnosis and appropriated treatment trying to minimize the side effects to the patient and to the society. In the later, the financial cost is very important as in the last decade, the cost for the treatment of these fractures is very high with the increased hospitalization and the increased number of patients treated surgically [28].

Current literature supports the use of the Korres classification by both biomechanics experts [29] and surgeons [30]. This is due to the fact that this classification is biomechanically oriented as it is clinically and surgically. It is pinpointed that it comprises all significant fracture types, it is more relevant to the biomechanics and cause of injury [29], it is useful in decision making concerning treatment and it is more simple to use in everyday clinical and surgical practice [29,30] for decision making.

The study of cases by Korres et al. revealed some directions for the development and treatment of these fractures. It is showed that type A and D fractures can and should be treated conservatively; they usually have a good prognosis. Type B fractures are prone to further complications and hence should be treated – in their majority surgically. Type C fractures need to be followed closely and in case of instability and/or late displacement have to be operated.

TABLE I. *The Korres classification and its treatment options*

Type	Treatment
A	Conservative
B	Surgical or Conservative
C1	Conservative or Surgical
C2	Conservative
D	Conservative

Conclusions

Fractures of the odontoid process represent a particular entity; they need a careful handling as their behavior is not easily predictable. Diagnosis of the correct type of fracture is very important. Complications due to multiple factors, are not rare and have to be carefully managed and treated. Pseudarthrosis is the most common complication related to many factors the most important being the instability at the fracture site.

The Korres classification has been proven successful and is now considered more realistic as it is simple, it includes the whole spectrum of fractures, it refers to one anatomical structure (the odontoid process), it correlates to the biomechanics of the axis, it indicates the prognosis and it suggests the management of the fracture.

The study of cases by Korres, et al. revealed some directions for the development and treatment of these fractures. It is showed that type A and D fractures can and should be treated conservatively; they usually have a good prognosis. Type B fractures are prone to further complications and hence should be treated – in their majority surgically.

Type C fractures need to be followed closely and in case of instability and/or late displacement have to be operated.

Conflict of interest:
The authors declared no conflicts of interest.

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READY - MADE CITATION

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ΠΕΡΙΛΗΨΗ

Περιγράφονται και αξιολογούνται τα συστήματα ταξινόμησης των καταγμάτων του οδόντος ενώ αναπτύσσεται η ταξινόμηση «Κορρέ».

ΛΕΞΕΙΣ ΚΛΕΙΔΙΑ: Κατάγματος Οδόντος, Ταξινόμηση Κορρέ