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INTERLAMINAR ATLANTO-AXIAL FUSION FOR INSTABILITY

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At the Departments of Neurosurgery and Orthopaedic Surgery in Odense 36 patients were treated with atlanto-axial interlaminar fusion. The operation was performed jointly by the neurosurgeon and orthopaedic surgeon, working as a team, using a specially developed technique. Two bone grafts from the iliac crest were shaped, with grooves for the two laminae, and fixed with wire on the right and left side. Postoperative immobilization in a Minerva jacket was maintained for 3 months and a plastic collar was worn for another 3 months.

Twenty-one patients had odontoid fractures, five of them with pseudarthrosis. Ten had atlanto-axial instability caused by rheumatoid arthritis. The instability was horizontal in seven cases, with a mean distance of 12 mm from the odontoid process to the anterior arch of the atlas. Five patients had vertical dislocation with the apex of the odontoid process protruding 8 mm (mean) cranially to the foramen magnum, and eight had cord signs. Two patients had an os odontoideum with instability after trauma, and three had other lesions.

At follow-up, at least 1 year after the operation, all fusions were solid, and all fractures but one had healed. The rheumatoid patients had achieved great relief of symptoms with minimum restriction of movement in the cervical spine. The indications for operation on patients with rheumatoid arthritis are very restrictive.

Key words: atlanto-axial instability; rheumatoid arthritis, atlanto-axial instability; atlanto-axial interlaminar fusion

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Several surgical methods for stabilizing traumatic as well as non-traumatic atlanto-axial instability have recently been published and are being used with increasing frequency. Indications as well as methods have differed widely, and there has also been an appreciable difference in the results.

At the Odense Hospital we have developed, by collaboration between orthopaedic surgeon (KHS) and neurosurgeon (JH), our own technique which has been used without modification since 1966. The indications, the technique itself, and the results will be reported below.

PATIENTS AND METHODS

From November 1966 to April 1975, a total of 36 patients underwent atlanto-axial fusion. There were 21 males and 15 females with ages ranging from 10–78 years (Table 1). Twenty-one had fracture or pseudarthrosis of the odontoid process, 10 atlanto-axial instability because of rheumatoid arthritis, and two an unstable os odontoideum following trauma. An 11-year-old boy had a fixed, inveterate rotation dislocation, a 10-year-old girl a fixed posture of the head following upon tonsillitis and atlanto-axial instability (Grisel's syndrome) (Grisel 1930), and one patient had hangman's fracture which normally we treat conservatively (Termansen 1974).

In the course of the study period the number of operations increased (Table 2), reflecting an increased surgical activity. Half the patients had cord signs.

Fracture and pseudarthrosis of the odontoid process. Among the 21 males, 10 were between 17 and 24 years of age. Five of the male group had pseudarthrosis and had their operation an average of 7 (3–17) months after the accident. Fourteen fractures had been sustained in traffic accidents. Six had not been recognized primarily, and three developed pseudarthrosis. One patient had an operation for a fracture of the lower leg before the fracture of the odontoid process was diagnosed. In 12 instances the diagnosis was not made until tomography was done. We used our previously reported classification into *high* and *low* fractures (Husby & Sørensen 1974). Seventeen fractures were high and four low; all were unstable. High fractures are unstable more often than low ones. Seven were pre-treated with cranial traction, four with bed rest on a double mattress with backward bent head, and eight with plastic collars. A number of low, stable fractures were treated conservatively.

A total of 25 patients had been involved in accidents. Nine had concussion and two contusion of the brain, seven had cord signs, and nine other injuries (4 extremity fractures, 4 cranial fractures, and 1 a fracture of the posterior arch of the atlas).

Table 3 lists the severity of the dislocation of the odontoid process. Only three patients had no primary dislocation or angulation. The dislocation amounted to up to 13 mm and the angulation up to 37°. Several patients had considerable angulation as well as dislocation.

Rheumatoid arthritis. At operation, the ten patients averaged 63 years of age (range 48–72), and the mean duration of rheumatoid arthritis was 21 years. Seven had been on a lengthy course of cortisone medication, eight had cord signs or cerebro-vascular deficit symptoms, and this was decisive in the indications. From Table 4 it is apparent that radiology showed considerable horizontal instability, the distance between the anterior edge of the odontoid process and the anterior arch of the atlas being 6–22, mean 12 mm. Five had vertical dislocation, the tip of the odontoid process protruding 3–15, mean 8 mm, up above the level of the foramen magnum (the McRae line) which it should not normally exceed. Radiology, often tomography, revealed in most of these patients widespread destructive and degenerative changes of the odontoid process and the region on the whole. All ten patients had extensive arthritic sequelae and degeneration of the cervical discs and small joints, typical of rheumatoid arthritis (Rana et al. 1973). All had severe rheumatoid arthritis with severe deformity of the extremity joints, and all were on disablement or old-age pension.

Preoperatively three patients were treated with backward bent head on a double mattress, and five were treated for a varying period of time with a supporting neck collar (Camp model). The rheumatoid patients were subjected to operation only on very strict indications, viz., neurological deficits or radiological changes so severe that there was a risk of a progressive or total cord lesion. Patients with less severe symptoms and signs were treated conservatively.

Table 1. Sex ratio, age distribution, and diagnoses in patients treated with posterior atlanto-axial spondylodesis

Age, years	10–49	50–78
21 males	17	4
15 females	2	13
Odontoid fracture pseudarthrosis	13	8
Rheumatoid arthritis	1	9
Os odontoideum + trauma	2	—
Other conditions	3	—

Table 2. Classification into periods showing that the number of fusion operations has been increasing

	Odontoid fracture or pseudarthrosis	Rheumatoid arthritis	Other conditions	Total
Nov. 15th 1966–1968 incl.	4	—	—	4
1969–1971 incl.	7	2	3	12
1972–May 1975 incl.	10	8	2	20
Cord signs	5	8	2	15

Table 3. Dislocation and angulation in fracture or pseudarthrosis of the odontoid process in 21 patients (cf. Table 5)

Dislocation of odontoid process	Forward	Backward	Right	Left	Total
Number of patients	*9*	*5*	*1*	*2*	*15*
Lateral dislocation					
mean mm	5	7	5	4	
range mm	1–10	3–13	—	2–6	
Number of patients	*3*	*9*	*3*	*3*	*17*
Angulation (degrees)					
mean	25°	19°	10°	6°	
range	20–30°	5–37°	5–16°	3–12°	
			Normal position 3		

Table 4. Data for 10 patients with rheumatoid arthritis

	Dislocation of odontoid process		
	Horizontal	Vertical	Horizontal + vertical
10 patients	5	1	4
Mean age 63 years	54–70	63	48–72
Mean duration of rheumatoid arthritis (years)	24	17	21
No. of pts. having cortisone medication (6 mo– 21 yrs.)	3	1	3
Cord or neurovascular deficit signs	5	1	2
Distance (max.) from ant. arch of atlas to odontoid process	13	—	11
Range, mm	6–22		8–13

METHODS

When the distance between the atlas and odontoid process was increased, the patient was pre-treated with backward bent head on a double mattress, the upper mattress reaching only to the shoulders. The decision regarding the indications was made jointly by the orthopaedic surgeon and the neurosurgeon and the operation itself was performed by both surgeons working as a team. All the staff must be made aware of the risk caused by the instability.

The patient is anaesthetized and intubated supine, and cranial traction is established (Blackburn tongs) to be on the safe side and to facilitate reduction. Thereafter, the patient is turned over to lie prone, his head on a special head rest fastened to the operating table (Figure 1), and his trunk on a special table used in operations for slipped disc, the median part of the trunk being free. The head is positioned bent 5–10° backward. The neurosurgeon exposes, through a midline incision, the posterior aspect of the atlantic and axial arches and occipital bone

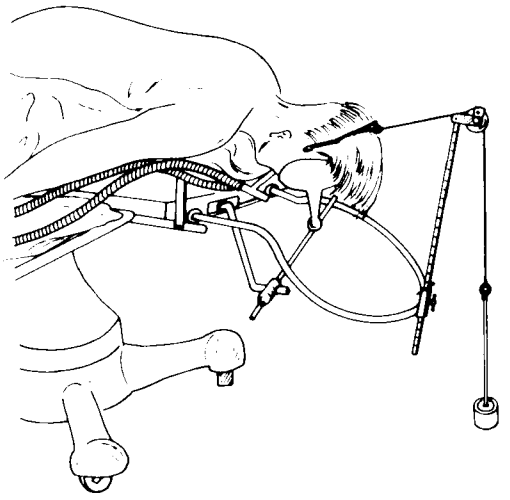


Figure 1. The patient's position on the operating table, his head on the specially constructed head rest. Cranial traction has been established.

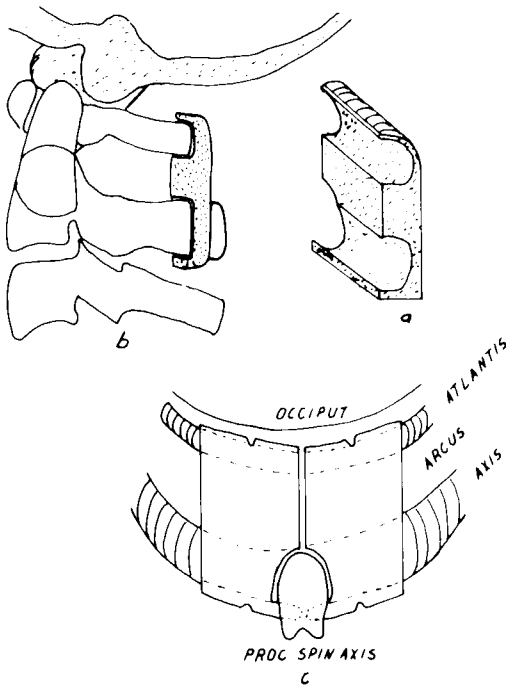
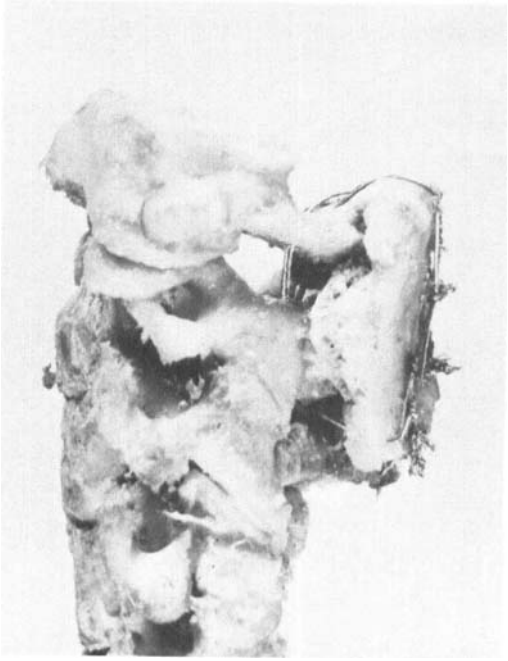


Figure 2. The shaping of the grafts and their placement.

behind the foramen magnum and cuts off the compact bone on the posterior aspect of the two arches and at the base of the spinous process of the axis. A spun, stainless steel wire is passed cranio-caudally anteriorly to the arches of the atlas and axis on the right side and another one on the left.

The orthopaedic surgeon removes from the iliac crest posteriorly on the left two bone grafts, about 2 cm wide and about 3 cm long, as required according to measurements, and comprising the lamina externa, half the crest, and underlying spongy bone. In the presence of osteoporosis or slender bones, the lamina interna is included as well. In each graft a groove is shaped just beneath the crest (Figure 2) to fit the atlantic arch, so that the crest firmly grips the upper edge. Farther down, a groove for the axial arch is made, and the bony prominence between the two grooves on the graft fits the distance between the two arches and projects between them. A corner distally-centrally in each graft is cut off at the level of the spinous process of the axis. The middle of the upper and lower edges is notched to accommodate the steel wires which are now tied, on the right and on the left side, so that the grafts are pressed forward into contact with the two arches. Two strong needle holders are used to tighten the wires. The free ends of the steel wire from the right and left side are tied transversely, both above and below the spinous process. This presses the grafts even more firmly, and the two arches cannot be pulled towards each other. The wounds are closed. The patient is laid supine in bed with sand bags at the sides of his head after the cranial traction has been removed. The patient is taken out of bed to stand twice daily, but is not allowed to move his head. After the sutures have been removed on the 10th day, a felt-padded Minerva jacket is applied. Three months after the operation the patient is re-admitted for removal of the plaster cast and lateral tomography. If union has occurred, he is discharged with a plastic collar to be worn for 3 months, and after radiography during anterior and posterior bending to secure stability, he is given brief instructions for training of the cervical and occipital muscles. One year after the operation he attends a clinical and radiological follow-up examination.

In two patients with fracture of the odontoid process, C_3 was included in the fusion (congenital synostosis of C_2, C_3, and C_4, fracture of lateral occipital condyle). In 21 cases the grafts consisted of only half the thickness of the iliac crest and in 15 cases full thickness iliac bone was used. Seven of these latter patients had rheumatoid arthritis and six had been treated with steroids; two of them had quite severe osteoporosis. In four very slim patients a mini-Minerva jacket was applied, with plaster plates down the anterior and posterior aspect of the trunk. All plaster casts



A

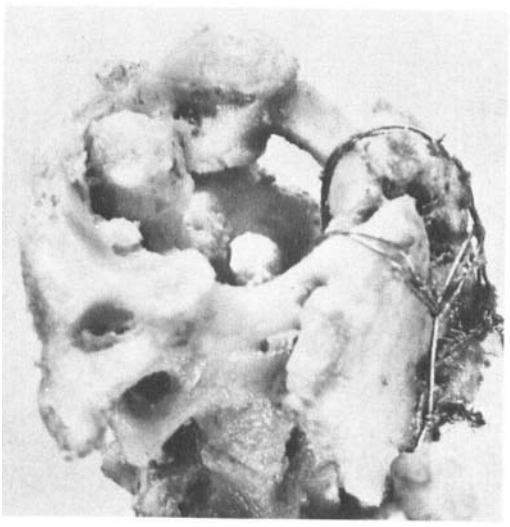


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Figure 3. Autopsy specimen of a cervical spine treated by spondylodesis 4 months before the patient died. The grafts are solidly fused (cf. text).
A: Lateral view.
B: Oblique postero-lateral view.

were padded with felt. Five patients with rheumatoid arthritis wore the supporting neck collar for 4–9 months and one for 35 months (severe osteoporosis and a long course of cortisone medication.

RESULTS

Thirty-five patients were seen at follow-up 1–5, mean 2 years 2 months, after the operation. A woman, aged 54, and treated with steroids for 15 years because of rheumatoid arthritis, died 4 months after the operation of pulmonary embolism, preceded by two attacks of pneumonia. At autopsy the upper part of the cervical spine was removed. There was solid union at the site of the spondylodesis (Figure 3).

All the spondylodeses had united (Figures 4, 5). In one patient odontoid non-union was still present 13 months after the operation, but this was of no clinical significance, as the spondylodesis was solid. In a 77-year-old patient only the posterior

Table 5. Position of odontoid process after healing of the spondylodesis (cf. Table 3)

Dislocation of odontoid process	Forward	Backward	Right	Left	Total (preop.)
No. of patients	1	2	0	0	3 (14)
Lateral dislocation (mm)	3	2–6	—	—	
No. of patients	1	8	1	3	13 (14)
Angulation, mean	19°	19°	6°	6°	
Angulation range	—	18–27°	—	6–12°	

Normal position: 8 patients (preop.: 3 patients).

A

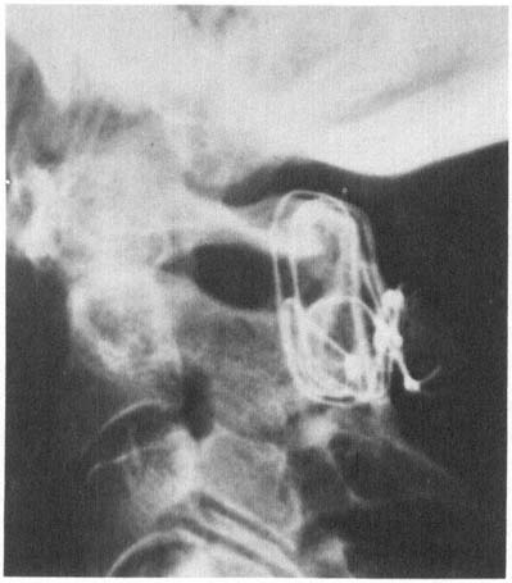

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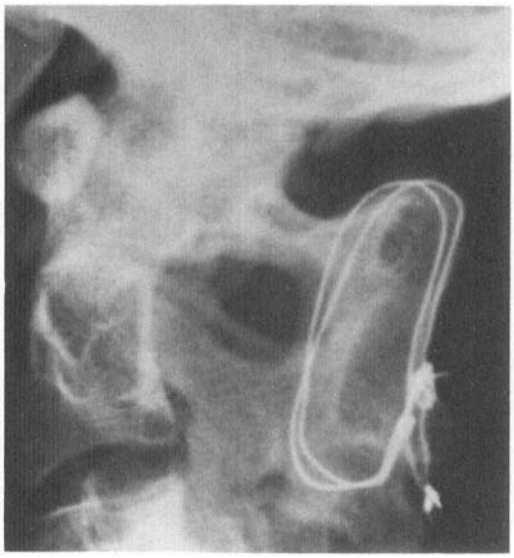
Figure 4. 70-year-old woman with a 20-year history of non-steroid-treated rheumatoid arthritis.
A: Lateral view prior to operation. The distance between the odontoid process and the anterior arch of the atlas is 14 mm.
B: Lateral view 35 months after the operation. Spondylodesis solidly healed. Odontoid process in the normal anatomical position.



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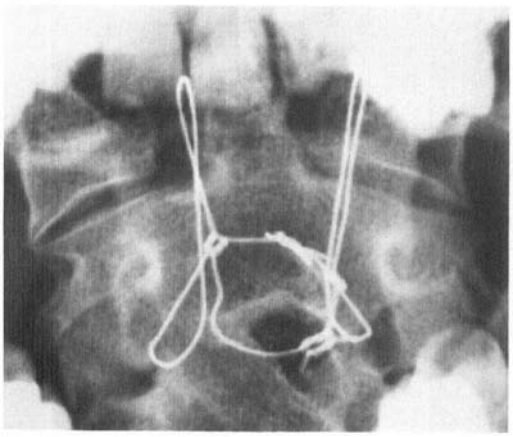

B

Figure 5. 22-year-old man with a high, unstable fracture of the odontoid process.
A: Lateral view 25 months after the operation shows solid healing of the spondylodesis as well as odontoid process. The ondontoid process is tilted backwards 15°.
B: Anteroposterior view illustrating the placement of the steel wires.

quarter of the odontoid fracture had united 1 year after the operation. In one case one of the grafts took almost 2 years to unite with the atlas, but this did not involve symptoms or a prolonged period of wearing a collar.

In the odontoid fractures considerable improvement of the position was obtained (Table 5), and in five cases there was a normal anatomical position. Sixteen of the patients with odontoid fracture were symptom-free, four had mild, periodical fatigue or pain at the back of the neck, and one had constant pain. (This was a 77-year-old woman in whom the odontoid process had been tilted backwards 24°, and the fracture had united only in the posterior one-quarter. She exhibited severe spondylosis around the 5th disc and osteoarthrosis in all small joints as well as the joint between C_1 and C_2). There were no sequelae to neurolesions. Seventeen patients had gone back to work an average of 7 months after the operation, while four were still on pension.

Six of the nine rheumatoid arthritics seen at follow-up had been largely relieved of their symptoms of atlanto-axial instability. Two had mild pain periodically or a feeling of stiffness. The cord signs had disappeared or considerably decreased except in one case. Tomography showed solid healing of the spondylodesis in all. The horizontal dislocation of the odontoid process had been abolished in five, and in the others the mean distance from the odontoid process to the anterior arch of the atlas was 7 mm (5–10) as compared with 11 mm prior to the operation. Central dislocation had been reduced by 2–4 mm in two patients, but was unchanged in the others. In one patient the odontoid process was tilted backwards 20° as against 23° before the operation (in relation to a plane through the anterior and posterior atlantic arches). Two patients died 15 and 41 months after the operation, so that a total of three of these ten patients in a fairly poor condition died, all of causes unrelated to the atlanto-axial instability.

The spondylodeses had healed solidly in five patients with various more uncommon diseases, and all of them were working. One with an os odontoideum and instability following trauma still had pain at the back of the neck and in the left arm as well as disturbances of sensibility down to the ring and little fingers. The spondylodesis had healed, with the odontoid bone tilted forwards 18° and displaced 5 mm to the right and 7 mm forward together with the entire axis in relation to C_1. At the operation 7 months after the trauma it had been impossible to improve the position. The spondylodesis was found to have extended to C_3 2 years after the operation.

Mobility in the cervical spine in young patients having an otherwise normal cervical spine was in fact normal, but in elderly patients with degenerative changes it was restricted, in a few to a troublesome extent.

There were no infections, problems of wound healing, or thromboembolic complications. There were no calcifications of the soft tissues surrounding the spondylodesis, no steel wires had broken, and there were no local symptoms. In one case the wing of the iliac bone fractured 2 weeks after the operation, close to the donor site, but there were no late sequelae.

DISCUSSION

Indications. After conservative treatment of unstable odontoid fractures there is a great risk of non-union. In cases of high fractures as many as 36 per cent do not unite (Anderson & D'Alonzo 1974), but regardless of the site of the fracture, non-union is common (Schatzker et al. 1971: 61 per cent, Ramadier et al. 1976: 35 per cent). In non-dislocated fractures Schatzker et al. demonstrated non-union in 42 per cent, in posterior dislocation in as many as 89 per cent. The frequency of life-threatening complications in cases of instability has not been reported, but a few authors have described

such cases (Hentzer & Schalimtzek 1971). Recent publications have therefore justly advocated fusion in atlanto-axial instability, if a reliable result is not obtained by conservative treatment, as this can prevent life-threatening complications to which these patients are easily exposed in modern road traffic (Schatzker et al. 1971, McGrav & Rusch 1973, Anderson & D'Alonzo 1974, and others). In doubtful cases we have assessed the stability by forward and backward bending while manual traction is exerted on the skull by an experienced orthopaedic surgeon or neurosurgeon during fluoroscopy.

Atlanto-axial instability has been demonstrated in 25 per cent of hospitalized patients with rheumatoid arthritis (Conlon et al. 1966), and fatal cord compression is more common than previously assumed (Mikulowski et al. 1975). Among 130 patients with rheumatoid arthritis and atlanto-axial instability, but without neurological deficit, Smith et al. (1972) found 5–14 years later that 52 had died, 4 had cord signs, and 6 had symptoms of vertebral artery ischaemia. As the instability most often gives rise to symptoms at the most severe stage of the disease in very disabled patients, most authors reserve operation for patients who develop cord or vascular deficit symptoms or increasing pain and stiffness despite conservative treatment (Meijers et al. 1974, Ferlic et al. 1975, Thomas 1975, Brattström & Granholm 1976, Jones & Kaufmann 1976), especially if the symptoms progress or if acute, neurological episodes occur (Rana et al. 1973). We have acted on similar principles. In the presence of severe osteoporosis, we have abstained from operation.

Technique. Gallie (1939) set down the principles for stabilizing instability in the cervical spine, viz., fixation of the two involved vertebrae by steel wires and simultaneous insertion of bone grafts from the ileum or tibia. Gallie used this principle with increasing frequency for injuries in all parts of the cervical spine. It has later been designated as a Gallie atlanto-axial fusion, although he did not accurately describe the technique or report the results. With minor modifications, and with widely different postoperative immobilization (cranial traction, Minerva jacket, neck collar, etc.) it has been used by many workers (Simmonds & Fielding 1967, Schatzker et al. 1971, McGrav & Rusch 1973, Anderson & D'Alonzo 1974, Fielding et al. 1976, Ramadier et al. 1976).

Others have used occipito-cervical fusion, with grafts fixed to the occipital bone and C_1, C_2, or possibly C_3 (Patte & Rose 1969, Grantham et al. 1969, Newman & Sweetnam 1969, Meijers et al. 1974).

Instead of bone grafts Kelly et al. (1972) used acrylic bone cement and steel wires to fix C_1–C_3, whereas Brattström & Granholm (1976) use this for occipito-cervical fixation, but these materials include cases complicated by infection or broken steel wires, and the results can hardly be assessed definitely until a longer follow-up period has passed.

The *results* of atlanto-axial fusion by a single bone graft (Gallie fusion) are said to be good, with few complications and rather few cases of non-union. Simmonds & Fielding (1967) obtained union in all their 35 cases, Schatzker et al. (1971) in 13 out of 15 (true, in 9 cases the fracture of the odontoid process did not heal, but this was of subordinate importance), McGrav & Rusch (1975) in 14 out of 15, and Anderson & D'Alonzo (1974) in 16 out of 18 cases. Ramadier & Aleon (1975) obtained healing in 93 per cent of 90 operated cases (64 atlanto-axial, 25 occipito-cervical) and Fielding et al. (1976) in 44 out of 46 atlanto-axially fused and in 9 out of 11 occipito-cervically fused cases.

After occipito-cervical fusion Patte & Rose (1969) reported healing in 12, Newman & Sweetnam (1969) in 9, and Grantham (1969 in 8 out of 9, whereas Meijers et al. (1974) had healing in 11 out of 12 operated patients (one patient died postoperatively). Brattström & Granholm (1976) have reported excellent results in 21 out of 28 operated patients for whom they used acrylic bone cement and occipito-cervical steel wire fixation.

In the various materials the position of the odontoid process and axis in relation to the atlas has not been systematically described after healing of the spondylodesis. By our technique the desired position is obtained because of the interposition of the graft between the arches of C_1 and C_2, and extra stabilization is afforded by the two grafts forming an angle with each other.

Our material confirms that the surgical treatment of atlanto-axial instability can be rendered devoid of complications and its result reliable. However, the indications for this operation will remain strict in the case of patients with rheumatoid arthritis owing to their already poor prognosis.

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