Gut: 8 Fälle. Volle körperliche Leistungsfähigkeit, zeitweise mäßige Beschwerden. GDW nicht unter −10°.

Mäßig: 5 Fälle. Reduzierte körperliche Leistungsfähigkeit, zeitweise stärkere Beschwerden. GDW nicht unter −15°.

Schlecht: 4 Fälle. Deutlich reduzierte körperliche Leistungsfähigkeit, häufige Beschwerden. GDW unter −15°.

Komplikationen

Ein deutlicher Verlust der Wirbelkörperhöhe und eine Zunahme der Kyphose war bei vier translaminär verschraubten (SI = 0,70–0,62; GDW = −9° bis −18°) und bei fünf verplatteten Fällen (SI = 0,82–0,71; GDW = −12° bis −22°) zu beobachten. Eine eindeutige Erklärung konnte dafür nicht gefunden werden.

Abgesehen von einigen nur oberflächlichen und ohne besondere Maßnahmen beherrschbaren Wundheilungsstörungen über der operierten Wirbelsäule kam es in einem Fall zum Wundinfekt im Bereiche der Spongiosaentnahmestelle am hinteren Beckenkamm, der durch konservative Lokalmaßnahmen zur Ausheilung gebracht werden konnte. In einem zweiten Fall trat trotz der üblichen Hypokoagulation eine tiefe Beinvenenthrombose auf, die aber zu keinen sekundären Komplikationen führte. In zwei verplatteten Fällen brachen die unteren Plattenschrauben nach je einem Jahr, was aber den weiteren Verlauf nicht nachteilig beeinflußte. Neurologisch mußte keine Verschlechterung hingenommen werden.

Experimentelle Druckprüfung an frischen und frakturierten, operierten Leichenwirbeln

Der Wert einer Spongiosaplastik zum Ersatz von Kortikalis- oder Spongiosadefekten nach Brüchen ist aus biologischer Sicht unbestritten, da dadurch die tragfähige Konsolidierung solcher Brüche beschleunigt, zum Teil aber auch erst möglich wird [27, 64]. Wie sich gebrochene, vorwiegend spongiöse Knochen nach Reposition und Spongiosatransplantation rein mechanisch verhalten, wurde aber bisher nicht bearbeitet. Die Untersuchungen von Plaue [51–53] liefern klare Aussagen über das Stabilitätsverhalten von im Sinne der Kompression gebrochenen Wirbelkörpern. Die Experimente von Wörsdörfer [70] geben Auskunft über die Stabilität und Steifigkeit verschiedener dorsaler Fixationssysteme an unterschiedlich stabilen Frakturmodellen der thorakolumbalen Wirbelsäule unter reiner Biegebelastung. Beide experimentellen Arbeiten lassen aber keine Schlüsse auf das Verformungsverhalten von reponierten Wirbelbrüchen nach Defektauffüllung mit Spongiosa zu.

Um diese Frage zu klären, wurden unter statischen Versuchsbedingungen an frischen Leichenwirbeln Druckversuche durchgeführt, um Kompressionsbrüche zu erzeugen. Die Kraft-Wegdiagramme wurden aufgezeichnet. Die Ergebnisse im Bruchverhalten von frischen Brust- und Lendenwirbelkörpern sind mit denen von Plaue [52] vergleichbar. Die Erzeugung dieser Kompressionsbrüche war notwendige Voraussetzung dafür, die Stabilität bzw. das Verformungsverhalten von zunächst gebrochenen, dann transpedikulär aufgerichteten und mit Spongiosa aufgefüllten Wirbeln experimentell zu prüfen.

Versuchsmaterial

Die Versuche wurden an 19 ganzen Wirbeln des thorakolumbalen Übergangsbereiches (D 11–L 4) von vier männlichen Leichen (18, 34, 44 und 76 Jahre) durchgeführt, die am Institut für Gerichtliche Medizin der Universität Innsbruck[1] wegen zunächst unklarer Todesursache obduziert wurden. Bei keiner Leiche bestanden krankhafte Veränderungen der Knochen. Nach der Obduktion wurde die Wirbelsäule von D 9 bis L 5 als ganzes entnommen und die Wirbel einzeln freipräpariert. Die Bandscheiben wurden gänzlich entfernt, Periost und Längsbänder wurden belassen. Die Entnahme der Wirbel, die Präparation und die Versuche wurden bei einer Raumtemperatur von ca. 19° durchgeführt, zwischenzeitig wurden die Wirbel in Plastiksäcken eingeschweißt bei ca. 4° gelagert. Die Entnahme und Präparation der Wirbelsäule bzw. der Einzelwirbel erfolgte anläßlich der Obduktion einen Tag nach Eintritt des Todes, der erste Druckversuch wurde einen Tag später durchgeführt. Danach wurden die gebrochenen Wirbel nach der vorgestellten Operationsmethode transpedikulär reponiert und mit Spongiosa, die aus nicht geprüften Wirbelkörpern gewonnen wurde, aufgefüllt. Der zweite Druckversuch erfolgte einen Tag später. Es wurden ausschließlich ganze Wirbel mit Bögen und allen Fortsätzen geprüft. Von allen Versuchswirbeln wurden Röntgenbilder jeweils vor und nach den Druckversuchen angefertigt (Abb. 10).

Versuchsdurchführung

Die Druckversuche wurden auf der Schenck-Universalprüfmaschine im Labor des Institutes für Baustatik und

1 Herrn Univ.-Prof. Dr. R. Henn, Vorstand des Institutes für Gerichtliche Medizin, sei an dieser Stelle herzlich für die freundliche Unterstützung gedankt

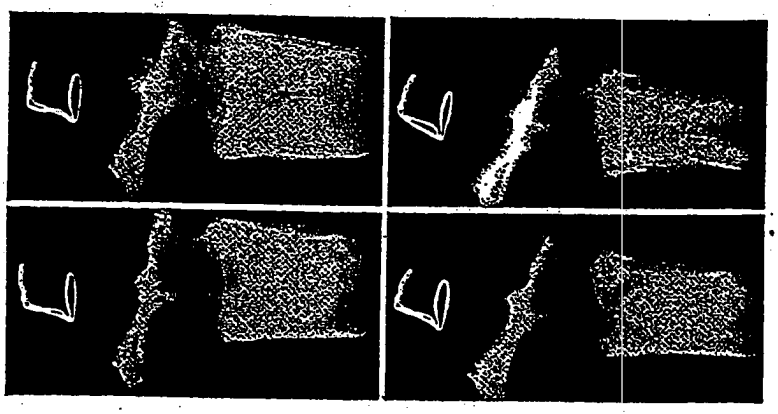


Abb. 10. Seitliche Röntgenbilder eines Versuchswirbels vor und nach dem ersten Druckversuch (obere Reihe), nach operativer Aufrichtung und Spongiosaplastik und nach dem zweiten Druckversuch (untere Reihe)

verstärkte Kunststoffe der Universität Innsbruck[2] durchgeführt. Die Druckkraft wurde in Anlehnung an die Versuche von Plaue [51] mit einer Verformungsgeschwindigkeit von 5 mm in 60 Sek weggesteuert auf den zu prüfenden Wirbelkörper aufgebracht. Um Unebenheiten der Grund- und Deckplattenflächen auszugleichen, wurde für jeden Wirbel für die Ober- und Unterseite eine eigene Lasteinleitungsplatte aus sandgefülltem Epoxydharz hergestellt. Um Schrägstellungen während des Versuches zu ermöglichen, wurde der obere Druckstempel mit einem Kugelgelenk versehen. Die Kraftmessung erfolgte mit einer 40 kN DMS-Kraftmeßdose. Zur Wegmessung wurde ein induktiver Wegaufnehmer W 250 verwendet. Die Kraft-Wegdiagramme wurden mit einem XY-Schreiber aufgezeichnet. – Die Versuche wurden jeweils nach einer Verformung um halbe Vorderwandhöhe beendet, um die Versuchswirbel nicht zu zermalmen.

Versuchsergebnisse

Druckversuche an frischen Leichenwirbeln. Die Druckkraft-Verformungskurven zeigen bei allen geprüften Wirbeln qualitativ drei charakteristische Bereiche (Abb. 11).

Bereich 1: Nach einer kurzen Kontaktphase steigt die aufnehmbare Druckkraft des Wirbels proportional mit der Verformung an. Es besteht hier ein linearer Zusammenhang zwischen Druckkraft und Verformung. Entlastet man den Wirbel vor Erreichen der Bruchlast, so geht die Verformung wiederum auf Null zurück, ist also reversibel. Dies entspricht einem linear-elastischen Werkstoffverhalten. Die aufnehmbare Druckkraft läßt sich bis zu einem charakteristischen Niveau, der Bruchlast, steigern. Diese ist bei allen Wirbeln zwar ausgeprägt, jedoch individuell (Alter) und je nach Segmenthöhe (Abb. 11) unterschiedlich. Sie bewegt sich im Bereich zwischen 5400 und 9700 N, im Durchschnitt bei 6800 N (Abb. 12).

Bereich 2: Nach Erreichen der Bruchlast nimmt die aufnehmbare Druckkraft bei Zunahme der Verformung als Ausdruck hoher Instabilität rasch ab. Diese Abnahme endet bei allen Wirbeln auf einem Niveau, das ca. 75% der Bruchlast beträgt. Dieser Bereich entspricht der Bruchphase nach Plaue [51].

Bereich 3: Die aufnehmbare Druckkraft bleibt bei zunehmender Vertikalverformung bis zu einem Höhenverlust von ca. 40% der ursprünglichen Vorderwandhöhe annähernd gleich. Danach ist wieder ein Anstieg der Druckkraft feststellbar. Somit setzt der komprimierte Wirbelkörper weiteren verformenden Kräften zunehmenden Widerstand entgegen. Charakteristisch für diesen Bereich 3 ist auch, daß die aufgebrachte Verformung bei Entlastung weitgehend eingeprägt bleibt.

Druckversuche an operierten Leichenwirbeln. Die nach dem ersten Druckversuch in der angegebenen Methode operierten Einzelwirbel wurden wiederum einer Druckprüfung unter gleichen Bedingungen wie die frischen unterzogen. Im Gegensatz zu jener frischer Wirbel zeigt die Druckkraft-Verformungskurve der operierten Wirbel keine charakteristischen Bereiche, sondern ist progressiv. Nach der Kontaktphase nimmt nämlich die aufnehmbare Druckkraft gegenüber der Verformung zunächst geringfügig und später immer stärker zu.

[2] Herrn Univ.-Prof. Dipl.-Ing. Dr. techn. K. Moser, Vorstand des Institutes für Baustatik und verstärkte Kunststoffe, sei an dieser Stelle herzlich für die freundliche Unterstützung gedankt

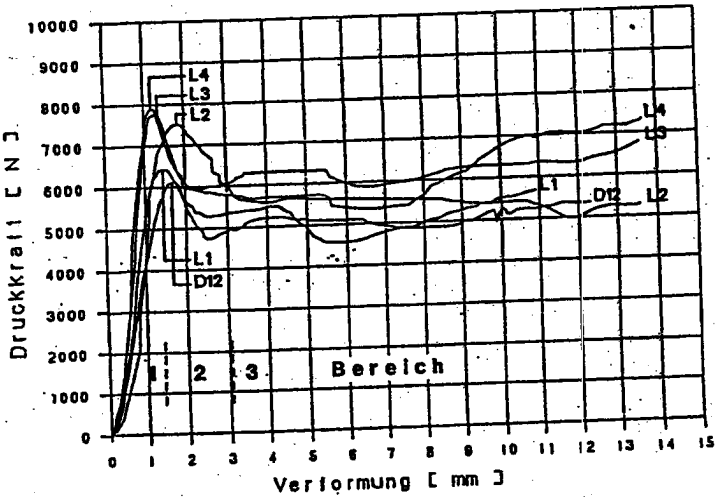


Abb. 11. Kraft-Wegdiagramm der Druckversuche an frischen Wirbeln D 12 bis L 4; 44 Jahre, männlich. Die Zahlen 1–3 bezeichnen die im Abschnitt: „Druckversuche an frischen Leichenwirbeln" erläuterten Bereiche

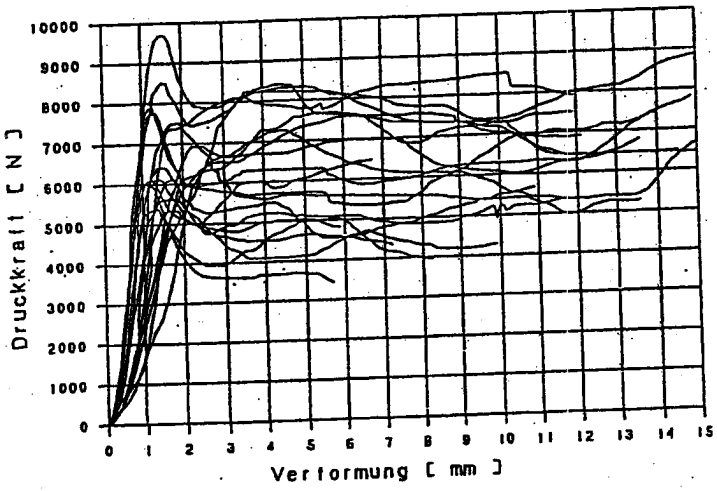


Abb. 12. Kraft-Wegdiagramme der Druckversuche an frischen Wirbeln ($n = 19$)

Während die Einzelwirbel im ersten Druckversuch bei zwar grundsätzlich ähnlichem Bruchverhalten je nach Alter und Segmenthöhe deutlich unterschiedliche Bruchlasten zeigen, ist das Verformungsverhalten der operierten Wirbel wesentlich einheitlicher (Abb. 13). – Bei Entlastung geht die aufgebrachte Verformung nur geringfügig zurück und bleibt eingeprägt. Damit zeigen die operierten Wirbel diesbezüglich ein ähnliches Verhalten wie frische Leichenwirbel im Bereich 3, da die operativ eingebrachte Spongiosa irreversibel verdichtet wird. Demnach sind operierte und neuerlich durch Kompression deformierte – ebenso wie frische Leichenwirbel im Bereich 3 – nicht durch ein elastisches, sondern durch ein plastisches Verformungsverhalten gekennzeichnet. Eine auch bei einmaliger Wiederbelastung erzeugte Verformung operierter Wirbel ist somit nicht mehr reversibel.

Diskussion

Auch bei Wirbelbrüchen im thorakolumbalen Übergangsbereich ist eine anatomische Form nur bei exakter Reposition, eine dauerhafte Stabilität nur bei tragfähigem knöchernen Durchbau zu erzielen. Beides läßt sich großteils durch konservative Behandlungsmethoden erreichen. Probleme stellen aber gedeckt irreponible bzw. durch Kompression hochgradig deformierte Wirbelkörperbrüche dar. Solche Verletzungen sind zwar grundsätzlich durch eine ventrale Fusion sanierbar, diese Technik ist aber als Standardmethode

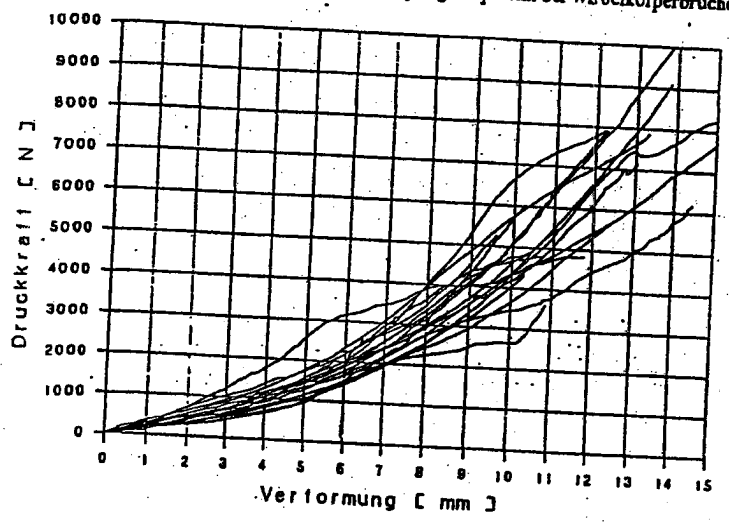


Abb. 13. Kraft-Wegdiagramme der Druckversuche an operierten Wirbeln ($n = 19$)

zu aufwendig. Allgemein werden deshalb für diese Region dorsale Stabilisierungen bevorzugt. Ein Nachteil dorsaler Fusionstechniken besteht darin, daß nicht jede Fraktur durch Distraktion, die ja nicht unmittelbar am verletzten Wirbel angreift, ausreichend reponiert werden kann. Über einen Kanal durch die Bogenwurzel aber gelingt es, mit einfachen Instrumenten die meist keilförmig deformierten Wirbelkörper von innen her direkt zu reponieren. Anschließend wir die durch die Fraktur bzw. instrumentelle Reposition entstandene Höhle mit autologer Spongiosa aufgefüllt, was eine rasche knöcherne Konsolidierung sichert.

Experimentell wurde das Verformungsverhalten von frakturierten und dann transpedikulär reponierten und mit Spongiosa aufgefüllten Wirbeln unter Druckbelastung untersucht. Dabei zeigte sich, daß eine auch nur einmalige Verformung solcher Wirbel eingeprägt bleibt. Aus der Druckkraft-Verformungskurve operierter Leichenwirbel läßt sich unter Zugrundelegung der von Nachemson [48] ermittelten intradiskalen Druckwerte in vivo ableiten, daß bereits physiologische Belastungen wie aufrechter Stand oder Sitzen Druckkräfte erzeugen, die ohne zusätzliche stabilisierende Maßnahmen zu einer irreversiblen Deformierung des operierten Wirbels führen würden. Die von uns durchgeführten mono- bzw. bisegmentalen Fusionen alleine bieten aber mit Sicherheit lediglich eine begrenzte Übungsstabilität, so daß bis zur weitgehenden knöchernen Konsolidierung der Fraktur ein reklinierendes Rahmenstützmieder notwendig ist. Dies stellt aber bei konsequent durchgeführter Miedergymnastik keinen entscheidenden Nachteil dar.

In 80% der Fälle wurde ein sehr gutes bis gutes, in 11% ein mäßiges und in 9% ein schlechtes Ergebnis erzielt. Wenn man berücksichtigt, daß es sich beim vorgestellten Krankengut ausschließlich um hochgradig deformierte bzw. instabile Brüche handelt, so ist trotz eines Korrekturverlustes in neun Fällen eine Kyphose von durchschnittlich 3,7° im Verletzungsbereich doch als gutes Gesamtergebnis zu werten.

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Transpedicular Reduction and Cancellous Bone Grafting Procedures in Fractures of Vertebral Bodies of the Lower Thoracic and Lumbar Spine

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Summary (in English): To avoid post-traumatic kyphosis, severely deformed and unstable fractures of vertebral bodies of the thoraco -lumbar area are increasingly treated operatively. A new operative technique is presented based on 4 years of experience. This technique offers the possibility of directly repositioning fractured vertebral bodies by a posterior approach. Access into the vertebra is a drill hole following the central axis of the pedicle. With the aid of an impactor, the deformity can usually be reduced quite easily. To prevent late deformities and promote bone healing, the central cavity of the vertebra is then filled with autogenous cancellous bone chips. The following dorsal fusion only extends to one or two motions segments. Stabilization is secured by means of translaminar screwing or plate fixation. The 44 cases operated upon were examined after an average follow-up time of 26 months. The fractured vertebrae showed mainly a wedge-shaped deformity with an average loss of 47% of the height of the anterior vertebral wall. The vertebrae treated by the method presented, showed average end results of only 7% loss of the anterior height and an average post-traumatic kyphosis of only 3.7°. These results are very satisfactory.

Summary in German: To avoid post-traumatic kyphosis, severely deformed and unstable fractures of vertebral bodies of the thoraco -lumbar area are increasingly treated operatively. A new operative technique is presented based on 4 years of experience. This technique offers the possibility of directly repositioning fractured vertebral bodies by a posterior approach. Access into the vertebra is a drill hole following he central axis of the pedicle that allows through a dorsal access through the roots of the arch a direct repositioning of the wounded vertebra and a cancellous bone grafting to fill up the defect. The following dorsal fusion only extends only to one or two motion segments. Together with a consistent physio-therapeutic follow-up treatment even after grave lesions of the spine it is possible to obtain favorable treatment results by means of the described method. This is shown in 44 cases after an average time of 26 months.

The aim of the treatment of the wounded spine consists in the restoration of the static, dynamic, and protective function of the spine. In principle, the same approach is used in lesions of the spine and in lesions of the extremities, by aspiring to restore the anatomic shape, the stability, and the normal, painless functioning.

Treatment methods

Conservative treatment

Lorenz Böhler [7] also in lesions of the spine advocated the principle of repositioning, retention, and treatment by exercise. On the contrary, Magnus [42] advocated the functional treatment. Both methods that were diametrically opposed to one another still decades ago, provide to a major extent good morphological and functional results [3, 12, 23, 33, 36, 49, 65, 69]. In the case of treatment in accordance with Böhler [8], however, time and again it is possible to observe a secondary caking together of the erected vertebrae [2, 12, 50, 63, 77, 80, 81]. In general, Magnus renounces the repositioning and retention [19, 29, 65, 74]. Frequently after a conservative treatment late complaints occur whose cause is mainly to be found in a posttraumatic kyphosis [2, 10, 36, 38, 45, 62, 69, 71, 73].

Operative treatment

Despite partially quite different views, [4, 5, 22, 28] the operative repositioning and stabilization of spine lesions is more and more gaining ground also in the area of the thorax-lumbar transition [3, 6, 18, 24, 25, 30, 32, 39, 40, 59, 66, 72, 77].

In this context, it is possible to stabilize from the dorsal direction by means of rods [9, 18, 20, 37], by means of plates [46, 56] or by means of the internal [41]or external [17] fastener. The implants are applied in the sense of the distraction or support or in the sense of compression or a tension chord [15, 75]. Osteosyntheses in the narrower meaning of the word (exact direct fragment repositioning, intergragmentary compression, stabilization with fracture-bridging implants) are not possible. Rather, these are operation methods in which it is possible indirectly to maintain the repositioning result by temporary spondylodeses with implants. Such a dorsal temporary spondylodesis becomes definitive by an addition of cancellous and cortico-cancellous chips to the posterior vertebra segments.

In ventral spondylodeses, after resection, destroyed bone or disc tissue is replaced with chips with load-carrying capacity that are in most cases ensured by neutralization plates [32, 70]

In rare cases, also combined methods are recommended (anterior decompression and fusion, posterior stabilization) [54, 76].

Indications for an operation

At the University Clinic for Posttraumatic Surgery in Innsbruck, 245 stabilizing surgical operations have been conducted on the wounded spine since 1981. In this context, the following indications for an operation were complied with:

Absolute indications

Primarily in/complete paraplegias with a narrowing down of the spinal channel or at unstable lesions are such indications. A secondary occurrence or increase in neurological failures with a narrowing down of the spinal channel or unstable lesions.

Covered lesions that cannot be repositioned. Open lesions.

Relative indications

Lesions that make expect late damage in the shape of a secondary deformation an/or of a neurological deterioration.
Conditions with stable exercise must be created to facilitate medical care and early rehabilitation.
Course, already consolidated posttraumatic faulty positions.

Stabilization technique in the thoracic lumbar area. Our own procedure

Dorsal fusions

In the thoracic lumbar area we prefer dorsal fusions, since at least from the access they are simpler and are amenable to standardization, which seems to be important above all in emergency situations [47]. In this context, dependent on the situation, translaminar screwing according to Magerl [44], dorsal plate spondylodesis modified according to Roy-Camille [56, 57], or the external fastener are used. At present, the internal fastener is not available to us as yet. We do not perform stabilization with rods because of the long fusion distance. We consistently connect the dorsal fusion by implants with an interspinal, interlaminar, and sometimes also an intertransversal cancellous bone grafting or cancellous cortical bone grafting that, however, is strictly limited to the wounded moving segments.

Tranpedicular repositioning and cancellous bone grafting

Also in case of early repositioning of compression fractures and/or bursting fractures of vertebrae of the thoracic-lumbar area it is necessary to expect a successful repositioning in regard to the axis and to the vertebra shape with defects of the callous bone in the vertebra, after the fractured and internally impacted cancellous bone does not erect itself spontaneously in particular after massive compression. Even if quite generally in case of a sufficiently long outside or inside fastening of fractures in the cancellous bone area a gradual holing of cancellous bone defects takes place [11, 61], according to our experience the consolidation of such fractures is accelerated when filling up the defect with cancellous bone. This favorable effect is also to be expected in the case of vertebra fractures. Thus it was obvious not only to reposition and indirectly to stabilize vertebra fractures, but by analogy to the treatment of other fractures, in cases of mainly cancellous bones (tibia head etc.) to fill up defects with autologous cancellous bone, in order to thus ensure and to accelerate the healing of the fracture in a favorable manner. Magerl (Personal communication) had already performed that once in three cases, but had not published this.

After clear indications are already available about the diameter of the roots of the arches [60], we conduct investigations of corpse vertebrae and they show that via a central channel that is 6 mm wide through the root of the arch it is possible to reach practically every point of the anterior two thirds of the vertebrae with rams of different curvature without impairing the corticalis of the root of the arch itself and thus its stability.

In 1981 we performed for the first time transpedicular cancellous bone grafting in cases of wedge-like deformed compression fractures starting from a sagittal index according to Beck [1] of 0.6 and less [13]. At first we presupposed the possibility of a covered repositioning of the fracture. However, the first cases showed already that in cases of fresh fractures a repositioning of front edge fragments or of imprinted cover plates was possible also via the channel through the root of the arch with the instruments that at first had been conceived exclusively as cancellous bone impactors. From this experience, transpedicular cancellous bone grafting was developed to the method of transpedicular repositioning of vertebra fractures with following cancellous-bone grafting and dorsal fusion in the case of suitable fracture forms [14].

Contingent of patients

At the University Clinic for Posttraumatic Surgery from 1981 to October 1985 from a total of 112 dorsal stabilizations of fresh lesions of the lower thoracic and of the lumbar spine area about 57 cases were connected with transpedicular repositioning or cancellous bone grafting.

Follow-up examinations and evaluations were conducted in 44 cases, the average observation period is 26 months (from 6 to 49 months).

In this context, the patients were 15 females and 29 males, the average age was 28 years (from 15 to 52 years). Causes of the accidents were first of all traumas due to high speed (Table 1), affected was especially the 1st lumbar vertebra (Table 2). In six cases adjacent vertebrae were also wounded in the form of upper anterior edge fractures, in two cases there were in addition stable compression fractures of the thoracic spine. Neurologically speaking in two cases there were a complete and in eleven cases an incomplete paraplegia (Frankel [21] B-D)], in 31 cases there was a regular finding (Table 3). Nine patients had multiple wounds, but none was wounded in a way endangering his life.

23 patients were transferred from peripheral hospitals after an average of 4 days (0 to 21 days) to our clinic. In 23 cases, preoperative repositioning was performed and a gypsum corsage or a gypsum shell was applied. The operation took place on an average ten days (0 to 28 days) after the accident, complete mobilization took place on an average ten days (5 to 28 days) after the operation. The hospitalization in our clinic lasted on an average for 27 days (10 to 74 days). If one adds to it the outside hospitalization duration before the transfer, then the average result is 29 days (10 to 79 days). Eleven patients were treated further at rehabilitation centers.

Classification of the lesions

There is a series of subdivisions about the stability of the spine and about the classification of spine lesions [26, 33, 34, 44, 55, 78]. Since the introduction of computer tomography that provides us in addition to the anterior-posterior and lateral representation also a third level, namely the horizontal level, the knowledge about the location and the extent of spine lesions has essentially deepened [3, 67]. Probably the widest used classification was made by McAfee [43], who following Denis [16] subdivides the spine into three osteo-ligament columns, namely an anterior column (front longitudinal ligament, the anterior two thirds of the vertebra and of the inter-vertebral disk) and the posterior vertebral arch with

Table 1. Causes of accidents (n= 44)

Traffic accidents	(12)	Motor car drivers	3
		Driver's mates	6
		Motor cyclists	3
Sport accidents	(15)	Skiing	9
		Toboggan	1
		Mountain climbing	3
		Gliding and hang-gliding	2
Falling from height (tree, steep staircase, etc)			16
Contusion			1

Table 2. Fracture localization (n=44)

D11	D12	L1	L2	L3	L4
2	7	25	6	1	3

Table 3. Neurological findings in cases of accidents and during follow-up control, classified in accordance with Frankel [21] (n= 44)

	Accident	Control
A (complete paraplegia)	2	1
B (Residual sensibility available)	3	-
C (Useless sensorimotor system available)	6	-
D (Useful sensorimotor system available)	2	9
E (regular in neurological terms)	31	34

Table 4. Classification of the lesions according to McAfee [43]. Stabilization methods: TLV= translaminar screwing, RC= dorsal plate spondylodesis, FE= external fastener (n = 44)

	Total	TLV	RC	FE
1. Wedge-shaped compression fracture	10	7	3	-
2. Stable bursting fracture	11	7	4	
3. Unstable bursting fracture	7	-	6	1
4. Chance fracture	-	-	-	-
5. Flexion-distraction lesion	11	1	10	-
6. Translation lesion	5	-	5	-
Total	44	15	28	1

the appertaining processes, joint capsules, and ligaments). McAfee attributes the greatest importance to the middle segment like Roy-Camille to the comparable middle vertebral segment [58]. As the main wounding forces he considers axial compression and distraction, as well as transversal translation. In his classification he names six stable lesion forms.

Our 44 objective cases were listed on the basis of the X-ray- and CT pictures, as well as of the operation findings in accordance with this subdivision. At the same time with this, the technique of the performed sensibilization is indicated (Table 4).

Operation technique of transpedicular repositioning and cancellous bone grafting

At first, the patient is laid down on a radiation-permeable operation table in abdominal position, where the abdomen remains free of compression by bolstering the shoulders and the anterior crista iliaca. The arms are pointing towards the head. By longitudinal traction

at the arms and at the legs the spine lesion is set as far as possible under image converter control. In single cases, the traction is maintained through the entire duration of the operation. After marking the spinous process of the damaged vertebra on the skin, the uncovering is performed. A typical dorsomedial access ensues that is rather kept on a generous scale, in order to prevent skin necroses due to strong pulling of the surgical pincers. The fascia thoracolumbalis is severed in parallel along the spinous process line with diathermy. Then the paraspinal musculature is shoved off by means of chisels and scrapers subperiosteally en bloc mutually until the spinous process, the vertebral arches, and joint processes of the intended fusions distance are represented completely. The basis of the transverse processes is also to be visible, but at least well palpable.

Covered repositioned fracture

If a covered repositioned fracture exists, then at first with the aid of the typical landmarks [35, 56] the projection of the root of the arch's center of the fractured vertebra at both sides of the angle between the upper joint process and the transverse process basis is sought out and touched up. In this context, we keep to the indications of Magerl [41] (Fig. 1a) that provide a good accuracy. An exact preoperative study of the projections of the roots of the arches in the X-Ray picture makes it substantially easier to find out these places. Then the centers of the roots of the arches are marked by driving in short, 2 mm thick drilling wires, then the correctness of the position of these drilling wires is controlled by means of the image converter and corrected, if necessary. Now the roots of the arch are manually bored into the vertebra until ca. 40 mm deep with an ascending series of Steinmann nails from 3 to 6 mm, and in this context the direction is chosen about parallel to the covering plate and converging by 10 to 15 degrees forward (Fig. 1b). In this context, Steinmann nails in a sensitive manual boring always find the central way in the root of the arch. In the utilization of a drill here there rather seems to be a danger of perforating the corticalis of the root of the arch. By means of a narrow dissector then furthermore an entrance is made through the channel in the root of the arch into the vertebra itself, and in this context in general one will fall as it were into a cancellous bone defect hole in which often it is possible to palpate disc tissue that has penetrated here. This tissue can be distinguished by its consistence clearly from the cancellous bone and, so far as it can be palpated and reached, it is removed by means of little pincers. Then the existing cancellous bone in the vertebra is slightly pressed against the covering plate and the upper front edge (Fig. 2 upper line), and in this context we utilize rams with a different curvature with a diameter of 5 mm (Fig. 3). The whole maneuver is performed with the utilization of the image converter, and in this context due to increasing experience and to the utilization of a memory device it is possible decisively to reduce the exposure time. After a typical taking out of cortical cancellous bone and of cancellous bone chips from the posterior crista iliaca , the obtained cancellous bone is processed to chips with a maximum diameter of 5 mm. By means of a set of instruments developed for this purpose (Lang, personal

a b

Fig. 1a, b. Position of the bore channels on the vertebra. a landmarks according to Magerl: The point of intersection between the horizontal line that halves the transverse process and of the vertical line that is adjacent to the upper joint process from the outside corresponds to the projection of the center of the root of the arch b the bore channels converge forward

communication) (Fig. 4) then the cancellous bone defect cavity in the vertebra is in most cases simultaneously filled up above the roots of the arch. The transplant is specially pressed against the front wall, the front edge, and the covering plate,later also the channel in the root of the arch itself is filled with cancellous bone. For this about up to 30 ml of loosely heaped cancellous bone is required.

Covered irreducible fracture

If there is a covered irreducible fracture, then as described above, at first the roots of the arch of the fractured and of the adjacent upper and lower vertebra are sought out. Into the latter one, axially through the roots of the arch 40 to 50 mm long 4.5 corticalis screws are screwed into the vertebra so far that the screw-heads rise above the bone level dorsally still by a few mm. By means of two modified abdomen repositioning tongues that are put near these screw-heads distraction is exerted in a dosed manner. Owing to this, in general it is possible to restore at least the rear wall height of the fractured vertebra. If a more than 30% narrowing down of the spinal channel is known due to dislocated rear wall fragments, then the rear wall is revised in each case via an enlarged flavectomy by preserving the processes of the articulations after representation and by a careful pushing off of the dural sack. If necessary, dislocated fragments are repositioned by impacting or extirpated. Also the intervertebral disc of the wound height is inspected. If here the rear longitudinal ligament has been torn, then the disc is cleared out. Now the transpedicular repositioning follows, with maintaining the distraction. At first, as described above, the channels are inserted via the roots of the arch into the vertebra, then the vertebra is palpated throughout, and disc tissue that has penetrated into it is removed. Then by means of rams with a different curvature via the roots of the arch, the vertebra is repositioned from the inside, whereas in general the anterior portions of the covering plate and of the front edge must be raised, which is successful in most cases without any major expenditure of force (Fig. 2, lower line). Then the transpedicular cancellous bone grafting follows, when mostly during the insertion of the cancellous bone from time to time additional repositioning is performed and the cancellous bone is distributed advantageously.

Dorsal fusion

After the operation phase of transpedicular repositioning or cancellous bone grafting there ensues dorsal fusion that we keep to the least possible distance.

Fig.2 . Sketched out course of the operation procedure (details cf. Operation technique)

In this context, the stabilization technique in biomechanical terms depends above all on that degree of stability of the bone portions of the anterior and middle column according to Denis [16]. If only the front column, hence the front two thirds of the vertebra was compressed, then in most cases a translaminar screwing is sufficient with a wire nose with a tension chord action over the adjacent spinous processes. If in addition the third column is damaged, then propping by means of plates or of the outside fastener is necessary.

Translaminar screwing. This takes place after removing the cartilege from the small articulations in accordance with the technique of Magerl [41]at the height of the injured moving segment. If the supraspinal and interspinal ligaments have been torn, then they are resected, a cortical cancellous bone H-chip is fitted in the corresponding spinous processes, and a wire nose with the action of a tension chord is fastened under tension around these two processes. After touching up the spinous processes and arches of the vertebrae of the fusion region, then additional cancellous bone chips and cortical cancellous bone chips are added, while strictly keeping in mind not to surpass the fusion distance that is monosegemental in such a case. If there are still enough chips available, then cancellous bone is put laso between the transverse processes.

Dorsal plate spondylodeses modified in accordance with Roy-Camille [47, 57]. At first one side the abdomen repositioning tongues are removed, the opposite side continues to be fastened under distraction. After measuring the distance between the screw-heads, correspondingly long plates are chosen and preliminarily bent slightly in an overcorrected manner in the sense of luminar lordosis. As implants, notched plates or narrow edged-punched plates are used with or without a stem. These three types of plates allow any distance of the holes standing at the end of plates in steps of ca. 4mm, so that the initially instrumental distraction by means of the expanding tongues is also maintained by the implants. Now the first plate is loosely fastened via the assigned screw holes in the vertebrae adjacent to the damaged vertebra after making the plate bed ready. For this purpose in most cases 6.5 cancellous bone screws [68] with a continuous thread are used. After removing the second abdomen repositioning tongues, the second plate is fastened in the same manner, then in alternation the screws are definitively tightened. By the preliminary bending of the plates a further increase of lordosis is obtained, the installation in low distraction ensures the height of the rear wall. Contrary to Roy-Camille, who recommends the stabilization in each case of two moving segments above and under the damaged vertebra, we include in each case only the corresponding upper and lower immediately adjacent segment into the plate spondelodesis. Thus the dorsal fusion is kept as short as possible. Further on, the procedure is as in translaminar screwing, but in this context, the definitive fusion distance extends only over two moving segments, that is, three vertebra heights. After drainage and repeated displacement of the paraspinal musculature, the wound is closed in layers.

Follow-up treatment

Postoperatively the patients are laid down flat in the bed, the lumbar lordosis is bolstered with a soft pad.

Fig. 3 a, b. Cancellous bone rams with different curvature

Fig. 4, a, b Cancellous bone funnels with impactor

After the wound pain has ebbed down, from the third postoperative day onwards, at first isometric exercises of the dorsal and abdominal musculature are started, at the same time the extremities are moved thoroughly. On the fourth to the sixth day in ventral sagging a plaster cast is made, so as to manufacture a removable framework support corsage. After its completion the patients are completely mobilized on an average from the tenth postoperative day (5^{th} to 28^{th} day). At the same time for the duration of immobilization, gymnastics with a corsage under the guidance of a physiotherapist is started, which is absolutely essential for the dynamic stabilization of the spine. The corsage is worn for three months without interruption, then for six more weeks only during the day. In single cases, after the definitive removal of the corsage, additionally a special type of spinal gymnastics was prescribed to improve the mobility.

Results

From 1981 to late April 1985, a transpedicular repositioning or cancellous bone grafting was performed on 50 patients. With a minimal follow-up observation time of six months it was possible to conduct follow-up examinations in 44 patients on an average 26 (6 to 49) months after the surgical operation. The clinical findings and all X-ray pictures were evaluated.

Clinical results

In the operated spine region itself eight patients complained about temporary painful tense up, three about irradiating pains dependent on loads, two about sensitivity to weather changes. In regard to physical loads, especially to lifting heavy loads, eight patients had local complaints, only two patients complained about subjective limitation of movement. Objectively in five patients there was a limitation of movements with a distance of fingers to the floor of more than 10 cm. Permanent pains existed in one patient. - Six patients had temporary, but slight complaints at the place of taking out the cancellous bone.

In neurological terms, one patient continued to have paraplegia, all the others attained a useful sensorimotor system. 31 patients were already primarily free from the viewpoint of neurology (Table 3).

For seven patients with physical work it became necessary to change their occupation. Two of them accepted easier physical work, four of them changed over to office work, only one of them remained incapable of doing any work. Only four patients subjectively considered themselves limited in their sports activities. Five patients complained about a general subjective slump in the capacity for work..

Radiological results

For all 44 patients, the lateral X-ray pictures were evaluated that were made immediately on the day of the accident (U), immediately after the operation (Op), and then in intervalsone, three, six months and then of six months to a year. From the injured or operated vertebra, the quotient from the front wall height and the rear front height (sagittal index according to Beck [1]) and the angle from the base plate and covering plate (KW= body angle) were measured. Furthermore, in each case additionally we determined the angle from the base plate of the adjacent lower vertebra (GDW= base plate to cover plate angle) , as well as the front height and the rear height of the intervertebral disc space (Fog.5). – Below, the KW and the GDW in the sense of lordosis are given a positive sign, and in the sense of kyphosis- a negative sign. – From these values it is possible to exactly follow in morphological terms the postoperative course of events both with regard to the concerned vertebra itself and with the spine axis in the damaged area. In this context it becomes manifest that on an average six months after the operation, the final state is almost attained that will be changed only insignificantly as compared with the one-year result. From this point in time the measured values remain constant, and therefore in the Tables 5 to 7 only the average values after two years are indicated.

For all 44 examined follow-up patients, from the sagittal indices of the adjacent vertebra of the penultimate vertebra a SI=0.94 was calculated as an average ideal value before the accident. Operatively an almost anatomical result is obtained with a repositioning from the value during the accident of SI=0.50 to SI= 0.92 (Table 5). Correspondingly favorable is also the correction of the KW by 17.1° from –20.4° to –3.3°. The loss of 0.05 or of 3.1° to the final result SI=0.87 or KW= -6.4° is insignificant and is hardly of any consequence.

On the contrary, the conditions with the GDW are less favorable. By the operation it is indeed possible to correct the spine axis in the damaged area by 15.3° from a GDW ≈ -8.6° to a GDW = +6.7 °, which corresponds approximately to a normal curvature of the lumbar region. However, in the course of one year, about 10.4° of this value is lost again until an average final value

Fig. 5. Measurement method. From the angles α or β the KW or the GDW are determined, from the front wall height and the rear wall height (arrows) the S1 is determined (abbreviations cf. Section: Radiological results).

Table 5. Average measured values of all cases (n= 44) (Abreviations cf. Section: Radiological results)

	SI	KW	GDW
U	0.50	-20.4	-8.6
Op	0.92	-3.3	+6.7
1 Mo	0.90	-4.8	+4.0
3 Mo	0.89	-5.0	+1.1
6 Mo	0.88	-5.5	-1.7
1 a	0.87	-6.4	-3.7
2 a	0.87	-6.4	-3.7

Table 6. Average measured values of the cases stabilized with translaminar screwing (n=15)

	SI	KW	GDW
U	0.51	-20.9	-7.3
Op	0.87	-5.7	+6.4
1 Mo	0.83	-8.2	+2.9
3 Mo	0.81	-8.7	+1.5
6 Mo	0.79	-8.9	-3.3
1 a	0.78	-10.3	-5.8
2 a	0.78	-10.3	-5.8

of a GDW=-3.7°.- With regard to the original value of the accident with a GDW= -8.6° however, it must be taken into account that the dorsal incumbent position of the patient alone, and in this position in the recently wounded patient usually also the lateral X-ray pictures are made, represents to a certain extent a repositioning already, and by this the effective axis conditions and thus the GDW are somewhat veiled. – The correction loss in the GDW is to be ascribed to 30% with 3.7° to a later sintering of the operated vertebra itself, but to 70% with 7.3° to the collapse of upper intervertebral disk that is also injured practically without any exception, but in part also to the lower intervertebral disk.-

Table 7. Average measured values of the cases (n= 79) stabilized with plates or in one case with an outside fastener (fixateur externe)

	SI	KW	GDW
U	0.50	-20.1	-9.2
Op	0.95	-2.1	+6.9
1 Mo	0.93	-3.0	+4.5
3 Mo	0.93	-3.1	+0.9
6 Mo	0.92	-3.6	-0.8
1 a	0.91	-4.3	-2.5
2a	0.91	-4.3-2.5	

a

b

c

d

Fig. 6 a –d . Average results of all cases (n=44). Calculated ideal value SI=0.94 (a). SI, KW and GDW at the moment of the accident (b) , postoperative, (c) and after one year (d) (Abbreviations cf. Section: Radiological results)

In Fig. 6 the average course is represented with regard to SI, KW, and GDW.

It was also examined, whether there are any differences with regard to the fracture forms and to the stabilization techniques (Table 4).

The 15 cases stabilized with translaminar screwing over only one moving segment are with one exception injuries that are to be considered as stable in a not repositioned condition (Fig.7). The calculated ideal value SI=0.91, as well the value of the accident SI= 0.51 only slightly deviate from the average value. However, the operation result or final result with SI = 0.87 or SI = 0.78 as well as the correction loss in the GDW of 12.2.° are still clearly below the average values (Table 6).

In the 29 cases stabilized over two moving segments (29 by means of plates, one by means of an outside fastener or fixateur externe) with the exception of the chance fraction all injury forms are found, of which 22 are unstable (Fig. 8 and 9). The calculated ideal value SI=0.95 and the value of the accident SI= 0.50 also only slightly deviate from the average. However, the operation result or final result with SI=0.95 or SI= 0.91, as well as the correction loss in the GDW of 9.4° are above the average values.

It is true that quite favorable results were obtained by means of both stabilization forms, but with regard to the final front wall height of the operated vertebra, the propping is superior to the tension chord. Also a certain role is played by the fact that in the cases stabilized by means of plates, the transpedical repositioning and cancellous bone grafting under distraction was performed, which also explains the primarily anatomic repositioning result.

In the X-ray picture, at first postoperatively the cancellous bone grafting is shown in most cases as a distinct granular compaction in the front vertebra portion, and this compaction then becomes ever more homogeneous in the course of 2 to 3 months. After 12 to 20 weeks the fractures are built through at least from the viewpoint of radiology.

Judgment of the results

By taking into consideration the clinical and radiological results the following judgment was made:

Very good: 27 cases. Complete physical capacity for work, no complaints. GDW not below –5°.

Fig.7 a –e. N.L. a 31-year old male, crash with a hang glider. Stable bursting fracture LWK 1 (a, b). Results postoperative (c) , after 1 year (d) and 4 years (e). Vertebral height is approximately constant, collapse of the upper, less of the lower intervertebral disk.

Fig. 8 a-e. G.P., a 28-year old male, mountain accident. Unstable bursting fracture LWK 1 (a, b) - Results postoperative (c), after 1 year (d), and 2 years (e). Free in neurological terms, body height constant, collapse of the upper intervertebral disk.

Fig. 9 a-e. M.M., a 17-year old girl, fell down from the 1st floor. Translation injury LWK (lumbar vertebra) 1 (a, b) , primarily complete paraplegia. Results postoperative (c) after 1 year (d) and 2 years (e). Vertebra height constant, collapse of both intervertebral discs. Essential improvement in neurological terms (Frankel D)

Good: 8 cases. Full physical capacity for work, temporarily moderate complaints. GDW not below –10°.

Bad: 5 cases. Clearly reduced physical capacity for work, frequent complaints. GDW below –15° .

Complications

A clear loss of the vertebra height and an increase of kyphosis were to be observed in 4 cases with translaminar screwing (SI= 0.70 to 0.62; GDW= - 9° to -18°) and in five cases

with plate stabilization (SI= 0.82 to 0.71; GDW= -12° to -22°). It was not possible to find an unambiguous explanation for this.

Apart from some only superficial wound healing disturbances that can be mastered without any special measures via the operated spine, in once case a wound infection in the area of the place occurred where the cancellous bone had been taken out at the rear iliac crest, but this infection could be brought to healing by means of conservative local measures. In a second case despite the usual hypocoagulation, a deep thrombosis in the vein of the leg occurred, but it resulted in no secondary complications. In two cases stabilized by plates, the lower plate screws broke after one year and another year, which did not disadvantageously affect the further course, however. No deterioration was to be put up with.

Experimental pressure test on fresh and fractured, operated corpse vertebrae

The value of cancellous bone grafting to replace defects of corticalis and of cancellous bone is uncontested from the viewpoint of biology, since thus the load-carrying consolidation of such fractures is accelerated and is even only allowed in this manner [27, 64]. How fractured, mainly cancellous bones behave in purely mechanical terms has not been studied as yet. The investigations by Plaue [51 - 53] provide clear statements about the stability behavior of vertebrae fractured in the sense of compression. The experiments by Wörsdorfer [79] provide information about the stability and stiffness of different dorsal fixation systems on fracture models with varying stability of the thoracolumbar spine under pure flexural load. Both experimental investigation, however, allow no conclusions about the deformation behavior of repositioned vertebra fractures after direct filling up with cancellous bone.

To elucidate this question, under static test conditions pressure tests were conducted on fresh corpse vertebrae, in order to produce compression fractures. The force-path diagrams were recorded. The results in fracture behavior of fresh thoracic and lumbar vertebrae can be compared with the results obtained by Plaue [52]. The production of these compression fractures was a necessary prerequisite for experimentally testing the stability or the deformation behavior at first of fractures, then of transpendicular erected vertebrae that were filled up with cancellous bone.

Test material

The tests were conducted on 19 whole vertebrae of the thoracolumbar transition area (D 11- 14 L) of four male corpses (aged 18, 34, 44, and 76 years) that were obducted at the Institute of Forensic Medicine of Innsbruck University [1] because of a death cause

[1] Here cordial thanks are extended to University Professor Dr. R. Henn, director of the Institute of ForensicMedicine, for his friendly support

that had been unclear at first. In no corpse were there any morbid changes of the bones. After obduction, the spine from D 9 to L 5 was taken out as a whole and the vertebrae were individually set free by preparation. The intervertebral discs were completely removed. The periosteum and the longitudinal ligaments were left untouched. Taking out the vertebrae, the preparation and the tests were conducted at a room temperature of 19°, meanwhile the vertebrae were welded into plastic sacks and stored at ca. 4°. The taking out and preparation of the spine or of the individual vertebrae took place at the occasion of the obduction one day after death had occurred, the first pressure test was conducted one day later. After that the fractured vertebrae were repositioned in a transpedicular manner in accordance with the described operation method and filled up with cancellous bone that had been obtained from untested vertebrae. The second pressure test took place one day later. Only whole vertebrae with the arches and with all processes were tested. X-rays pictures were made of all test vertebrae in each case before and after the pressure tests. (Fig. 10).

Execution of the tests

The tests were conducted at the Schenck universal test machine at the laboratory of the Institute of Structural Statics and

Fig. 10.Lateral X-ray pictures of a test vertebra before and after the first pressure test (upper line), after operative erection and cancellous bone grafting , and after the second pressure test (lower line)

and Reinforced Pastic Maerials of Innsbruck University [2]. In imitation of the experiments by Plaue [51], the pressure force was applied by path control with a deformation velocity of 5 mm in 60 seconds on the vertebra to be tested. To compensate the unevenness of the base plate surfaces and of the covering plate surfaces, for each vertebra for the upper and lower side its own load introduction plate was made of sand-filled epoxy resin. To allow inclined positions during the test, the upper pressure die was equipped with a ball-and-socket joint. To measure the path, an inductive path receiver was used.The force was measured by means of a 40 kN DMS dynamometer. The path-way diagrams were recorded by means of an XY-recorder. The tests were stopped in each case after a deformation by half the height of a front wall, so as not to crush the test vertebrae.

[2] Here we would like to cordially thank University Professor Dipl-Ing. Dr.tech, K. Moser, manager of the Institute for Structural Statics and Reinforced Plastic Materials, for his friendly support

Test results

Pressure tests with fresh corpse vertebrae. In all the tested vertebrae, the pressure force deformation curves showed three characteristic qualitative areas (Fig. 11)

Area 1: After a brief contact phase the vertebra's force that can be recorded will increase proportionally to the deformation. There is a linear interrelation between the pressure force and the deformation. If one relieves the vertebra before the fracture load is reached, then the deformation again returns to zero, hence it is reversible. This corresponds to a linear -elastic behavior of material. The pressure force that can be recorded can be increased until a characteristic level, the fracture load. In all vertebrae, this force is marked indeed, but varies individually (age) and according to the segment height (Fig.11). The fracture force varies in the area between 5400 and 9700 N, on an average near 6800 N (Fig. 12).

Area 2: After reaching the fracture load, the pressure force that can be recorded is rapidly decreased at an increasing deformation as an expression of high instability. In all vertebrae, this decrease will end on a level that amounts to ca. 75% of the fracture load. This area corresponds to the fracture phase according to Plaue [51].

Area 3: The pressure force that can be recorded remains approximately equal at an increasing vertical deformation until a loss of height of ca. 40% of the original height of the front wall. After that it is again possible to determine an increase in the pressure force. Thus the compressed vertebra opposes increasing resistance to further deforming forces. Characteristic for the area 3 is also the fact that the applied deformation remains impressed in case of relief.

Pressure tests on operated corpse vertebrae. The individual vertebrae that had been operated upon after the first pressure test with the indicated method were again subject to a pressure test under the same conditions as the fresh vertebrae. Contrary to fresh vertebrae, the pressure force deformation curve of the operated vertebrae showed no characteristic areas, but was progressive. Namely after the contact phase, the pressure force that can be recorded is at first slightly and later ever more significantly increased in regard to the deformation.

Fig. 11. Force-Path- diagram of the pressure tests on fresh vertebrae D 12 to L4; 44 years, male. The numbers 1 to 3 designate the areas explained in the section "Pressure tests on fresh corpse vertebrae"

Druckkraft n [N]	Pressure force [N]
1 2 3 Bereich	1 2 3 area
Veformung [mm]	Deformation [mm]

Fig. 12. Force-path diagrams of the pressure tests on fresh vertebrae ($n = 19$)

Druckkraft [N]	Pressure force [NB]
Verformung [mm]	Deformation [mm]

Whereas the individual vertebrae in the first pressure test indeed showed clearly distinguishable fracture loads at a principally similar fracture behavior in accordance with age and segment height, the deformation behavior of the operated vertebrae is essentially more uniform (Fig. 13).- During a relief the applied deformation is reduced only insignificantly and remains impressed. Thus the operated vertebrae in this regard showed a similar behavior like fresh corpse vertebrae in the area 3, since the operatively introduced cancellous bone was compacted in an irreversible manner. Accordingly, operated vertebrae and vertebrae deformed again by compression – like the fresh corpse vertebrae in section 3- are characterized not by an elastic, but by a plastic deformation behavior. Hence, a deformation of operated vertebrae is no longer reversible that has been produced even at a load that has been repeated once.

Discussion

Also in vertebra fractures in the thoracic-lumbar transition area, an anatomic shape can only be obtained with an exact repositioning, permanent stability can only be achieved by building through of bones that have a load-carrying capacity. Both objectives can be obtained to a great extent by conservative treatment methods. However, problems are raised by covered vertebra fractures that cannot be repositioned or that have been deformed to a high degree by compression. It is true that such injuries can obtain sanitation by a ventral fusion. However, this technique is too expensive as a standard method.

Fig.13. Force-path diagrams of the pressure tests on operated vertebrae ($n = 19$)

Druckkraft [N]	Pressure force [N]
Verformung [mm]	Deformation [mm]

Therefore in general, dorsal stabilizations are preferred for this region. One disadvantage of dorsal fusion techniques consists in the fact that not every fracture can be sufficiently repositioned by distraction that does not immediately attack the injured vertebra. However, via a channel through the root of the arch it becomes possible by means of simple instruments to reposition directly from the inside the vertebrae that are deformed mostly in a wedge shape. Later the cavity that has been formed by the fracture or by instrumental repositioning is filled up with autologous cancellous bone, which ensures a rapid bone consolidation.

By experiments we investigated the deformation behavior of fractured vertebrae that were then repositioned by transpedicular reduction and filled up with cancellous bone under pressure load. In this context, it was shown that an only one-time deformation of such vertebrae remains impressed. From the pressure force deformation curve of

operated corpse vertebrae it is possible to derive in vivo by taking as a basis the intradiscal pressure values determined by Nachemson [48] that already such physiological loads as upright standing or sitting will produce pressure forces that without any additional stabilizing precautions can result in an irreversible deformation of the operated vertebra. The mono-segmental or bi-segmental fusions alone carried out by us, however, with certainty offer only limited exercise stability, so that a reclining framework support corsage is necessary until a far-going bone consolidation of the fracture. Anyhow, with consistently conducted gymnastics using a corsage, this does not constitute a decisive drawback.

In 80% of the cases, a very good to good, in 11 % a moderate, and in 9% a bad result was obtained. If one considers that the presented cohort of patients has only fractures deformed to a high degree or unstable fractures, then despite a correction loss in nine cases, an average kyphosis of 3.7 ° in the area of the injury is still to be evaluated as a good total result.

Literature

In general, literature lists are not translated. However, if the client requires, it is possible in addition to translate the bibliographical data that are not written in English.

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