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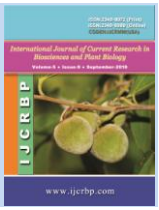

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Disadvantages of Stainless Steel Implant Compared to Carbon Fiber Reinforced Polymer for Vertebral Fracture

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ABSTRACT

The present study analyzed the surgical technique used for the replacement of damaged vertebral bodies of the thoracolumbar spine and the carbon fiber reinforced polymer (CFRP) cages that are used to replace the pathological vertebral bodies and it is advantages in comparison to the stainless steel implant. The biochemical properties of carbon composite materials used in spinal surgery was also analyzed. The surgical technique of CFRP implants may be divided into two distinct steps. i.e., assembling the components that will replace the pathological vertebral bodies and connecting the cage to an osteosynthetic system to immobilize the cage. The CFRP cages, made of Ultrapek polymer and AS-4 pyrolytic carbon fiber (AcroMed, Rotterdam, The Netherlands, are of different sizes and may be placed one on top of the other and fixed together with a titanium rod. These components are hollow to allow fragments of bone to be pressed manually into them and present threaded holes at 15, 30 and 90 degrees on the external surface, permitting the insertion of screws to connect the cage to an anterior or posterior osteosynthetic system. To date, we have used CFRP cages in 7 patients undergoing corporectomies. None of our patients have reported complications. CFRP implants offer several advantages compared with titanium or surgical grade stainless steel implants, demonstrating high versatility and outstanding biological and mechanical properties. Furthermore, CFRP implants are radiolucent and do not hinder radiographic evaluation of bone fusion, allowing for better follow-up studies.

Introduction

Carbon fiber reinforced polymer (CFRP) implants were initially introduced and used in vertebral surgery for posterior lumbar interbody fusion. The mechanical characterictics and principles on which the use of this material in posterior lumbar interbody fusion is based have been widely discussed (Brantigan et al., 1991; Brantigan et al., 1992). The aim of this report is to describe the advantages of surgical technique used for the replacement of the damaged vertebral bodies of

the thoracolumbar spine with similar-sized carbon fiber cages.

Materials and methods

The pre operative plan for the patients was a group of investigations done to exclude some cases from the study. Investigations include whole spine CT scan and MRI, cardiology and respiratory consultations, bone densiometry and calculation of body mass index. The excluded cases were morbid obesity with body mass index more than 40, chronic cardiac and respiratory diseases, epilepsy, osteoporotic patients, and spine metastasis. The CFRP cage (supplied by AcroMed, Rotterdam, The Netherlands) we used was constructed of long carbon fibers (Hercules AS-4 pyrolytic carbon fiber) enclosed in an Ultrapek polymer matrix (poly-ether0ketone-ether-ketone-ketone or PEKEKK). Its basic components come in three heights (11, 15 and 22 mm), each available in two transverse sections (thoracic [20 X 30 mm] and lumbar [30 X 40mml]. These components are hollow to allow fragments of cortical and spongiose bone to be manually pressed in to them and present screw holes at an angle of 90 degrees on the short side and 15 and 30 degrees on the long side (Fig. 1, A-D). The threaded holes allow the insertion of 5-mm screws, connecting the cage to an anterior (CASF or Kaneda; AcroMed) or posterior (VSP or Isola plates; AcroMed) osteosynthetic system. To date, this cage has been used in 7 corporectomies, using an anterior surgical approach, using a combined anterior and posterior surgical approach during the same period of anesthesia.

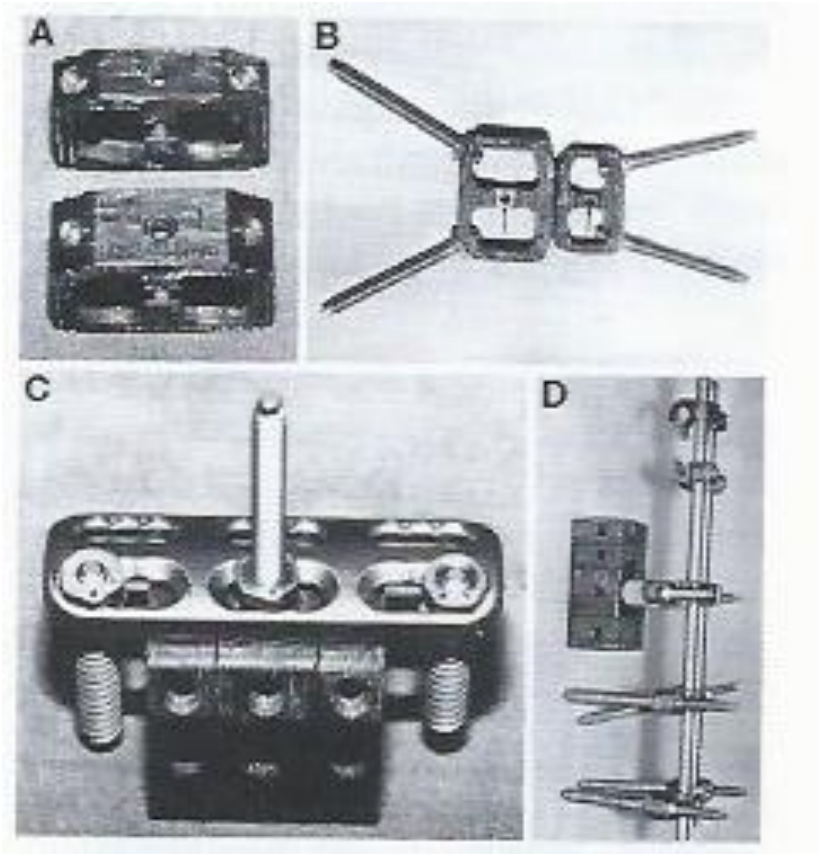

Fig. 1: The CFRP cage.

Patient population

Since 2014 (YEAR), 7 patients have undergone surgical procedure 5 men (71.5%) and 2 women (28.5%) [range 30-80 yr; mean, 50 yr] for reconstruction of spinal segments T4-L4 (Fig. 2).

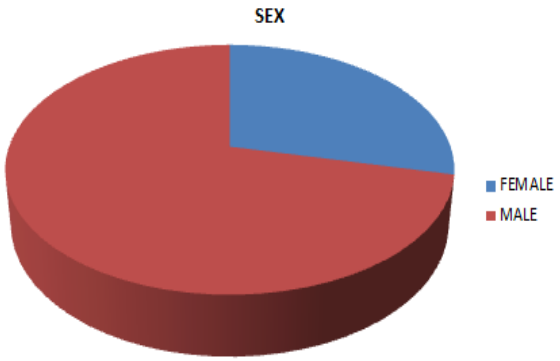

Fig. 2: Patient population

Results

Surgical technique

As stated in materials and methods, cages are of different sizes and may be placed one on top of the other, fixed together by means of a titanium rod. The titanium rod is inserted through an assembling hole present at the center of every cage and secured at one side with a nut and at the other side with a washer (Fig. 3A).

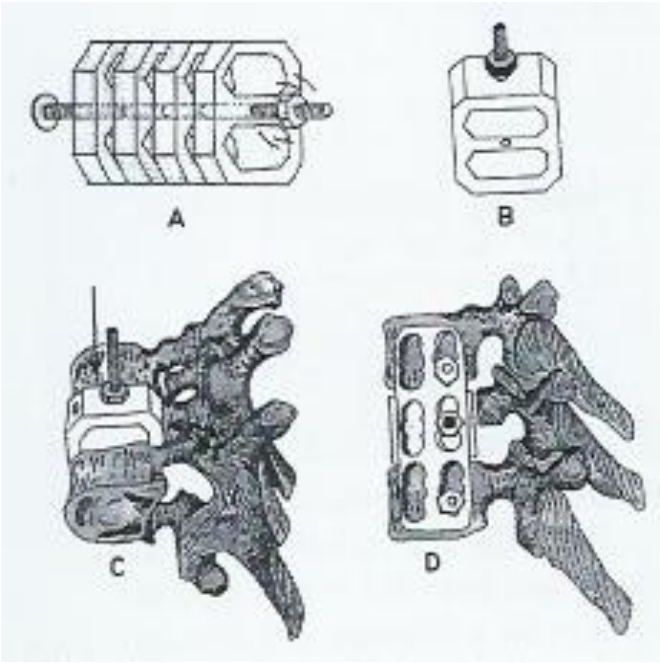

Fig. 3: The CFRP cage assembled for the study.

The CASF type plate (University plate) contains longitudinal slots to receive anterior and posterior bolts, inserted in the vertebral bodies above and under the respective pathological bodies. The assembled cage, however, may be connected to any other anterior fixation device that accepts a 5-mm screw.

For a correct surgical technique, it is essential to expose the vertebral body that is to be removed together with those on either side of it, so that the cage can be firmly fixed to the surrounding spinal segments. Once the pathological body has been exposed, first the intervertebral disc above and below it and then the vertebral body itself are removed. At this point, the posterior screws are inserted on the posterior face of the lateral surface of the bodies above and below the one removed.

The CASF plate is placed on the posterior bolts and fixed; subsequently, the anterior bolts are driven and secured to the plate itself. Exposure of the anterior face of the dural sac after removal of the vertebral body is very useful for deciding the driving direction of the screws; this is extremely important because if the direction of the screws is wrong, the spinal canal may be pierced. For this purpose, the CASF instrumentation included a temporary plate, simulating the definitive one, in which the posterior screw holes go in the opposite direction to the spinal canal.

The space that remains between the two vertebral plates after removal of the body is measured to assemble an implant a few millimeters longer by putting together two or more cages. The screws are then pulled slightly apart to allow positioning of the cage into which fragments of autologous bone taken from the rib have been placed (Fig. 4, A and B).

A 5-mm screw is inserted into the hole on the lateral surface of the cage that corresponds in line with the posterior slot in the CASF plate, and the cage is bolted to the plate (Fig. 3, B-D; Fig. 5, A and B; and Fig. 6, A and B).

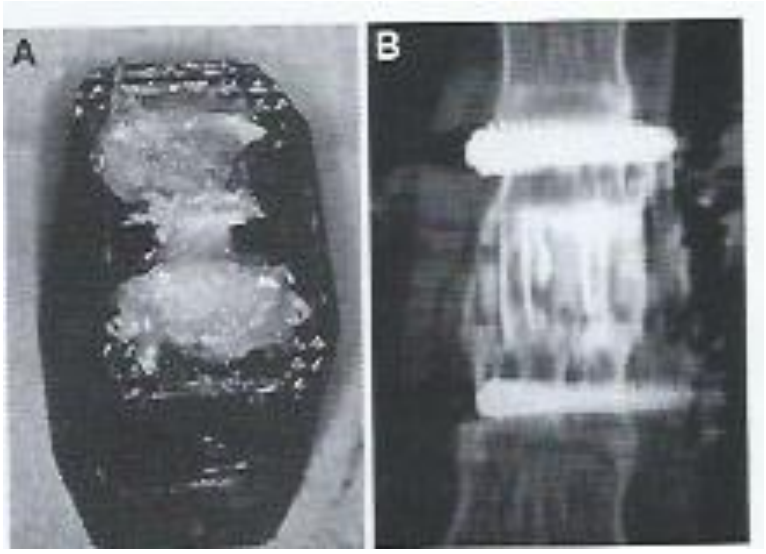

Fig. 4: Positioning of the cage.

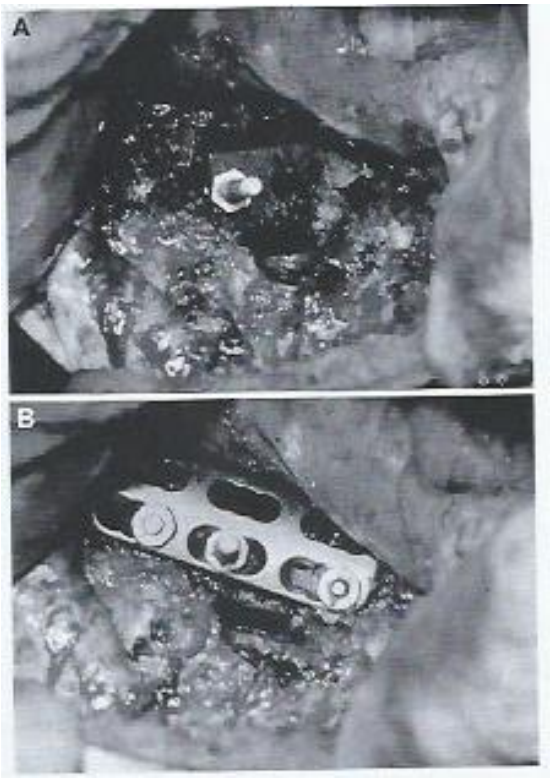

Fig. 5: The lateral surface of the cage.

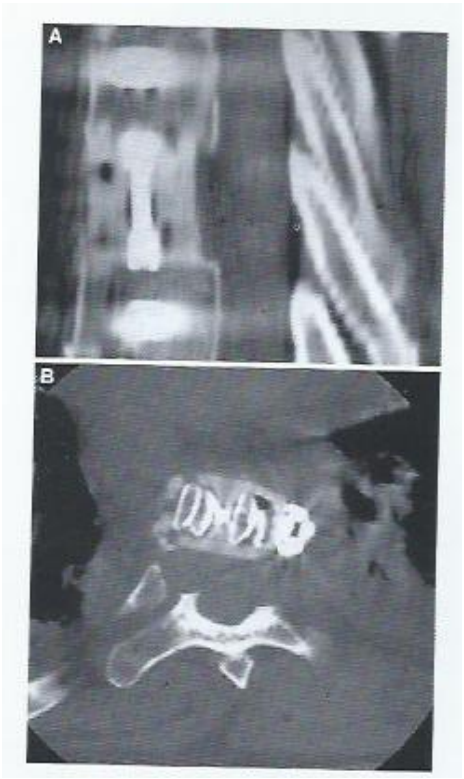

Fig. 6: Cage bolted to the plate.

Technical difficulties

To maintain low profile of the construct, it is important to remove the pathological body as completely as possible so that the lateral part of the cage is on the same level as the lateral part of the adjacent vertebral bodies. We have noted that it is also possible to fix the cage onto the adjacent vertebral bodies using a plate with a single series of holes without jeopardizing the stability of the construct. At the end of the procedure, the excess portion of each screw with respect to the profile

of the construct is cut off. After this has been performed, the cut surface of the screws may be rough, and thus we prefer to cover the plate with a dural patch anchored to the surrounding tissue.

Follow-up

To date, none of our patients has reported complications. All patients have been followed up approximately every 6 months for at least 1 year from the day of the operation. The system used for assessing the good results were clinical evaluations, spinal plain radiographs, and computed tomographic (CT) scans. All patients recovered to upright position within 2 weeks from the day of surgery. At the end of the follow-up routine, none of the patients complained about pain and the results of their examinations revealed no neurological complications. The radiological controls did not reveal any secondary implant dislocations and evidenced a successful and satisfying growth of the bone grafts in all patients, and, in some patients, revealed an inclusion of the cage in a solid fusion bone mass with the reconstruction of the anterior column.

Discussion

The CFRP implants such as vertebral body replacement cages, attention should be focused on the polymer matrix, because the mechanical and biological properties of the implant will be derived mainly from it. The biomechanics of the CFRP includes the cages we used for vertebral replacement consisted of Ultrapek / AS-carbon fiber.

Ultrapek is a high temperature thermoplastic polymer of the poly (aryl-ether-ketone) family with interesting properties for orthopedic load-bearing applications, including high strength, impact and fatigue resistance, solvent resistance, hydrolytic stability, and good fiber / matrix bonding, as well as being biologically inert, with no mutagenicity or carcinogenicity. Because carbon has been widely used before, there is an extensive literatures on its biocompatibility, safety, and mechanical properties. Although its function as a vehicle for autologous implants does not differ from other vertebral body replacement systems on the market; a CFRP implants offers several advantages compared with titanium or surgical grade stainless steel implants. It has an elasticity modulus similar to cortical bone, so that when bone grows through the cage, there is no mechanical modulus mismatch, and, under stress, the cage with and in the same manner as the bone. Furthermore, mechanical stress is transmitted to the bone chips with cage, promoting bone growth (according to Wolff's law, which states that bone will be reabsorb if not continuously subjected to a load [stress shielding]). To elicit maximum bone growth, bone fragments should be pressed into the cage (so-called "bone-packing"), allowing an even distribution of load.

Another advantage is that CFRP implants are radiolucent and therefore do not hinder radiographic evaluation of bone fusion. In our experience, CFRP implants also produced fewer artifacts on CT images than other implants constructed exclusively of titanium (Fig. 4, A and B). The composite material used for vertebral replacement cages is more biologically inert than titanium or stainless steel (metals exhibit a corrosive reaction to biological tissues) and demonstrates a high strength in all directional planes. Other mechanical features of CFRP cages have been discussed in the literature; they have proved to be excellent at both pull-out and compression tests (Brantigan et al., 1991). These properties make CFRP cages ideal vehicles for autologous implants.

One final characteristics of CFRP cages, demonstrating the versatility of the implant, is that they can be connected not only to a posterior system with screws inserted into the holes on the long side (15 degrees for thoracic segment and 30 degrees for the lumbar segment) (Fig. 1D), as described in Materials and Methods in the surgical technique section.

Conflict of interest statement

Authors declare that they have no conflict of interest.

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