THE ROLE OF CERAMICS IN SPINE STABILIZATION

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In spinal surgery, massive and strong bone grafts are required for reconstruction of the spinal column affected by a tumor, fracture or a degenerative disease with or without neurological involvement. Autogenous bone graft, though considered to be the best construct, is sometime not available and can not shaped accordingly to the need. Allograft is often limited in supply and has high incidence of infection, fracture and tranmission diseases.

Various materials have been used over the years as the alternatives to bone grafts in the construction of the diseased vertebra, such as metal, high density polyethylene, acrylic and ceramic protheses. Ceramics materials is considered superior to other materials because of its excellent property in bonding directly with adjacent living bone tissue.

Though most bioactive ceramics have not enough required strength to support high load, some newly developed ceramics prosthesis such as alumina ceramics, apatite-wallastonite containing glass-ceramics were reported to replace vertebral body successfully, especially in cases of metastatic spinal tumors.

INTRODUCTION

Patients with vertebral collapse and spinal cord compression caused by malignant disease or old spinal injury can induce severe spinal pain and motor or sensory disturbance, which seriously affect the quality of their lives. In cases of spinal metastasis, although radiotherapy remains the treatment of choice, quadriparesis or paraparesis secondary to an abnormal vertebral fracture cannot be successfully managed by irradiation alone. In case of kyphotic deformity, as the results of severe spinal fractures, laminectomy alone is not recommended because this would increase incidence of postoperative instability, besides not able to correct deformity, markedly incerase risk of neurological deterioration and reduce prospect of preserving or restoring ambulation.

Various surgical procedures to decompress the spinal cord, to restore spinal stability, or to correct deformity have been tried in such patients, but the results are not consistent[7]. Anterior decompression with stabilization, as a single stage procedure, is one of the acceptable approaches to relieve the pressure on the spinal cord and pave way for early mobilization. Together with the use of newly developed biomaterials it is possible that these goals might be achieved.

BIOMATERIALS FOR VERTEBRAL BODY REPLACEMENT GRAFT

The optimum conditions[2] for graft incorporation or substitution appear to include the biomechanical factors : the intensity of force or stress, acting at the graft-host interface should not exceed the failure value of graft or host material. Over a period of time, the average value of stress should not be zero. Cyclic variation in stress will be beneficial as long as it produces no significant relative motion at the interface. These desirable biomechanic considerations imply that a good graft will bear load without moving in the immediate postoperative period and shall function further until graft-host fusion.

Various materials have been used over the years to replace collapsed vertebra and to achieve stability.

A. Autogenous graft is usually used in anterior spinal construction. However this method always results in an invasion of the donor site and this may give rise to complications. For example, fracture of the grafted bone, pseudarthrosis, and kyphotic deformity correction loss sometimes occur in patients with osteoporosis because of the fragility of their osseous tissues. In patients with metastatic spinal tumor, the destruction of the grafted bone due to local recurrence of the tumor or postoperative radiotherapy leads to loss of stability of the reconstructed spine.

B. Allogenic graft poses many problems of high rate of infection, high incidence of pseudarthrosis, fracture of graft and transmission diseases. The supply is often limited and in certain countries this graft is socially not acceptable.

C. Metals[8] had been reported to use as an adjustable stainless steel prosthesis. It was implanted at the thoracic and lumbar levels after radical resection of primary intervertebral tumors. Because of their mechanical missmatches between stainless steel and human vertebral bone, it was not popularized. Until recently, titanium alloys is introduced to replace stainless steel in the form of mesh. However the outcome is still too early to be convinced.

D. Polymers[3,7,8] Methymethacrylate, polymerizing in situ, has been used for many year for replacement stabilization after vertebral resection and continue to be used as a complementary support where pins and rods have used to achieve primary stabilization. Acrylic cement has much to recommend in anatomical situations where it is difficult to wedge a graft firmly in place, namely, at the points where spinal lordosis is reversed at cervicothoracic and lumbosacral junctions. It can be molded to the desired shape, and its soldity is not affected by radiation. Use of cement ensures immediate stability and is bioinert. However, it is not a durable materials and fatigue fracture of the implanted cement occasionally occurs. Loosening also occurs in long standing cases.

E. Ceramics : Bioceramics, used as spinal prosthesis, composes of bioinert and bioactive ceramics. Because of their nearly similar compositions to human bone they are safely use clinically without tissue reaction. They are non-magnetic materials, so computed tomography scanning and magnetic resonance imaging can be used for follow-up evaluation after surgery.

Alumina ceramic is an example of bioinert ceramic. Biomechanical testing[6,11,12] has proved that it displays sufficient strength against compression, bending, and rotational stresses.[9]

The mechanical properties of ceramics comparing to human cortical bone are displayed in the following table.

Materials	Compressive strength	Bending strengtn	Elastic modules (Kg/mm^2)
Human cortical bone	16-18	16	1,800
Alumina	500	50-130	40,000
Ceravital	50	10	6,500
Dense HA	60-90	12	7,400
AWGC	108	23	11,700

Bioactive ceramics are hydroxyapatite (HA) tricalcium phosphate, bioglass, ceravital and apatite-wallastonite containing glass ceramic (AWGC). Their mechanical property is similar to bioinert ceramic. However, because of bioactivity at their surface they are capable of direct chemical bonding with the living host bone tissue.

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Owing to their excellent biocompatibility, high mechanical properties and direct chemical bonding capability ceramics has been used in replacement of the diseased vertebral body and stabilization of the spinal column.

Comparison of properties of bone grafts and biomaterials

	Autograft	Allograft	Ceramics	Polymers	Metals
Osteoconduction	+	+	+	-	-
Osteoinduction	+	+/-	-	-	-
Imm.torgue strength	++	++	+/++	++	++
Imm. stability	-	-	-	+	-
Chemical bonding	++	+	++	-	-

However, with limited experience, ceramics are used only in certain conditions[4],

(1) Patients with vertebral body collapse and spinal cord compression caused by malignant disease, Especially main metastatic lesion was within the vertebral body and the stability was lost or would soon be lost. And in cases the symptoms associated with spinal metastasis could not be relieved by conservative therapy eventhough spinal stability was maintained.

(2) Patients with fracture of vertebral body causing kyphotic deformity and instability. Especially those with acute progressive paresis and pain are also indicated.

The following were the results of selective literature reports used of ceramics.

Authors	Hoson *et al*[5]	Asone *et al*[1]	Shimizu *et al*[10]	Yamamuro *et al*[11]
Ceramics	Alumina	AWG-C	AWG-C	AWG-C
Added Component	Bone cement	Kenada device	Pedicle screw system	Ant.instrument
Surgical approach	Anterior	anterior	Posterior	Anterior
Patients	63	45	17	15
Indications	Tumors	Tumor & Fx	Spine disease	All
F.U.	3 yrs.	3 yrs.	<3 yrs.	<3 yrs.
Loosening	56% (9/16)	NO	NO	NO

According to Yamamuro *et al*[12], the AWGC prosthesis substituting for the vertebral body usually made a firm bond with the adjacent vertebral bone within 6 months, provied its dislocation did not occur at early postoperative stage. An average life-time[6] estimated from the fatigue of AWGC was 10 years under continuous loading of bending stress of 65 Mpa. in the simulated body fluid.

SUMMARY

Several bioactive and bioinert ceramics are acrailable for the purpose of structural reconstrucion of the spine. Because implantation of these ceramic vertebral prostheses do not provide immediate stability some forms of spinal fixation must be added and must maintain their function of stabilization until fusion, in casse of bioactive ceramics, occurs.

Spinal instrumentation, whether be it an anterior construct (eg,Kaneda's, Dunn's devices) or posterior construct (eg.Pedicle screw fixation system) besides allowing neural decompression, must provide adquate mechanical strength in a certain period of time against vertebral load, eventhough most of the vertebral load would transfer mainly to the vertebral prosthesis. Ceramic material, in the form of vertebral prosthesis, would serve this purpose and also bind to the living bone in a reasonably short period.

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