Evaluation of Bioabsorbable Multiamino Acid Copolymer/Nanohydroxyapatite/Calcium Sulfate Cage in a Goat Spine Model

Chunpeng Ren[1], Yueming Song[2], Youdi Xue[2], Xi Yang[2], Chunguang Zhou[2]

BACKGROUND: **Currently, polylactide is the most popular material used to made bioabsorbable cages but too-quick degradation and osteolysis around the cage have been reported in the literature. This study evaluated the fusion effect, biomechanical stability, and histologic characteristics of a novel bioabsorbable multiamino acid copolymer/nanohydroxyapatite/calcium sulfate (MAACP/n-HA/CS) interbody cage in a goat model of anterior cervical discectomy and fusion.**

METHODS: **A total of 24 goats underwent C3/C4 discectomy and fusion with 3 groups of intervertebral implants: MAACP/n-HA/CS cage group ($n = 8$), titanium cage group ($n = 8$), and autologous tricortical iliac crest bone group ($n = 8$). Disc space height and lordosis angle were measured pre- and postoperatively and after 4, 12, and 24 weeks. Range of motion (ROM) was evaluated through biomechanical testing. Histologic analysis was performed to evaluate fusion status and to detect any foreign body reactions associated with the bioabsorbable cages.**

RESULTS: **At 12 and 24 weeks, disc space height in MAACP/n-HA/CS cage group was greater than that of titanium cage group and tricortical iliac crest group ($P < 0.05$). Lordosis angle in MAACP/n-HA/CS cage group and titanium cage group were lower than that of tricortical iliac crest group ($P < 0.05$). Biomechanical test showed that ROM did not differ significantly between MAACP/n-HA/CS cage group and titanium cage group, whereas the value of ROM in bone graft group was the largest. Histologic evaluation showed a better interbody fusion in the MAACP/n-HA/CS cage group than in the other 2 groups. MAACP/n-HA/CS cage surface degraded and was absorbed at 24 weeks. All MAACP/n-HA/CS cages showed excellent biocompatibility.**

CONCLUSIONS: **MAACP/n-HA/CS cages can provide good fusion effect, enough biomechanical stability, and integrate closely with the surrounding bone.**

INTRODUCTION

Among the management options for cervical spondylosis or trauma, anterior cervical discectomy and fusion (ACDF) continues to be the most popular. It can achieve spinal cord and nerve root decompression while maintaining cervical physiologic curvature and segmental stability.[1-3] Meanwhile, there is not enough evidence to prove that ACDF can produce more adjacent segment degeneration than nonfusion surgery.[4]

Single-level ACDF with interbody implants such as tricortical iliac crest, metallic cages, carbon fiber, or polyether-ether-ketone cages consistently have yielded a high final fusion rate; however, some problems, such as interbody implants collapse, loosening, shift, the release of wear particles, and breakage of the cage, have been reported.[5-10] Currently, a growing number of multisegment intervertebral fusions require implanting cages with better properties to improve fusion rate and to reconstruct the segmental stability of cervical spine.

Bioabsorbable cages have comparable stiffness with that of bone, possibly resulting in an accelerated interbody fusion, and

Key words
- Bioresorbable cage
- Cervical spine
- Goat
- Intervertebral fusion
- Multiamino acid

Abbreviations and Acronyms
ACDF: Anterior cervical discectomy and fusion
DSH: Disc space height
LA: Lordosis angle
MAACP/n-HA/CS: Multiamino acid copolymer/nanohydroxyapatite/calcium sulfate
PCC: Polymer-calciumphosphate composite
PLDLLA: Poly (L-lactide-co-D, L-lactide)
ROM: Range of motion

From the [1]Department of Orthopedics, Lianyungang No.1 People' s Hospital, Xuzhou Academy of Medical Sciences, Lianyungang; and [2]Department of Orthopedics, West China Hospital, Sichuan University, Chengdu, China

To whom correspondence should be addressed: Chunpeng Ren, M.D. [E-mail: rcpspine@163.com]

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loading is transferred gradually to the healing bone along with the cage degrades.[11-13] Recently, a novel bioabsorbable cervical spine interbody fusion cage made of multiamino acid copolymer/nanohydroxyapatite/calcium sulfate (MAACP/n-HA/CS) has been developed.

The purpose of this study was to evaluate the in vivo performance of this bioabsorbable cage and to explore the ability to maintain disc space height, create biomechanical stability, and achieve interbody fusion by comparing it with a tricortical iliac crest bone graft and a titanium cage in a goat cervical spine interbody fusion model. The degradation of MAACP/n-HA/CS cages and tissue response to them also were observed.

MATERIALS AND METHODS

Study Design

A total of 24 Sichuan goats, 2 years of age, were divided into 3 groups randomly: group A, MAACP/n-HA/CS cage filled with autogenous iliac ($n = 8$); group B, titanium cage filled with autogenous iliac ($n = 8$); and group C, the tricortical iliac crest group ($n = 8$). Models of anterior goat C3/C4 discectomy and fusion with intervertebral implants were built.

Cage Description

The appearance of cages is shown in Figure 1. The bioabsorbable cages were made of MAACP/n-HA/CS (Sichuan National Nanotechnology Co., Ltd, Chengdu, Sichuan Province, China). The rate of amino acid incorporated in this compound material was 60%, nanohydroxyapatite was 30%, and calcium sulfate was 10%. The multiamino acid copolymers were made up of 6-aminocaproic acid, amino butyric acid, L-alanine, L-phenylalanine, L-proline, and hydroxyproline (the proportion was 108:2:6:7:6:2). The cages had an anatomical shape with a front length of 14 mm, rear length of 12.3 mm, central width of 11 mm, width of 9 mm on both sides, front height of 6 mm, and rear height of 5.09 mm, forming a slope of 6°, and was composed of dentate on both sides. The glass transition temperature was 175°C, and the initial axial compression strength was 80.74 ± 1.69 MPa ($n = 8$). The titanium cages, tricortical iliac crest bone, and MAACP/n-HA/CS cages had the same shape (Figure 1).

Surgical Technique and Postoperative Care

The animals underwent the operation under general anesthesia by intramuscular injection of xylazine hydrochloride, and 0.2% of chloralhydrate was administered intravenously for maintenance. The anterior part of the neck and the right iliac crest were prepared in a sterile fashion. A right anterolateral longitudinal incision was made in the neck to separate the vascular sheath and esophageal sheath, thereby exposing the tissues among the musculus longus colli. A Caspar distraction device (Kanghui Medical Instruments co., LTD, Changzhou, China) was used to excise the C3/C4 discs. The cartilage endplate was removed down to bleeding bone. The tricortical bone graft or cage filled with autologous iliac cancellous bone grafts was implanted into the intervertebral space. In all 3 groups, the motion segment C3/C4 was stabilized with a custom-made plate fixed with 3.0-mm screws to prevent anterior migration of the device. After plating, the wound was closed in layers. The animals were observed until they regained consciousness. Eight million units of penicillin were injected intramuscularly twice a day for 3 consecutive days.

All animals were examined and evaluated by radiograph before and 0, 4, 12, or 24 weeks after surgery. They were euthanized by intravenous injection of potassium chloride under pentobarbital sodium anesthesia at 12 weeks or 24 weeks after surgery, and the C3/C4 motion segment was harvested by removing peripheral muscles with preservation of ligaments. Biomechanical testing and histologic examinations were then performed.

Radiologic Assessment

At preoperative, postoperative and 4, 12, and 24 weeks, the changes of C3/C4 disc space height (DSH) and C3/C4 lordosis angle (LA) were observed through cervical lateral radiographs. Average DSH was calculated from anterior, middle, and posterior DSH measurements (i.e., aDSH + mDSH + pDSH/3). LA was measured as the angle from the C3 posterior vertebral body line to the C4 posterior vertebral body line. At 12 and 24 weeks, the

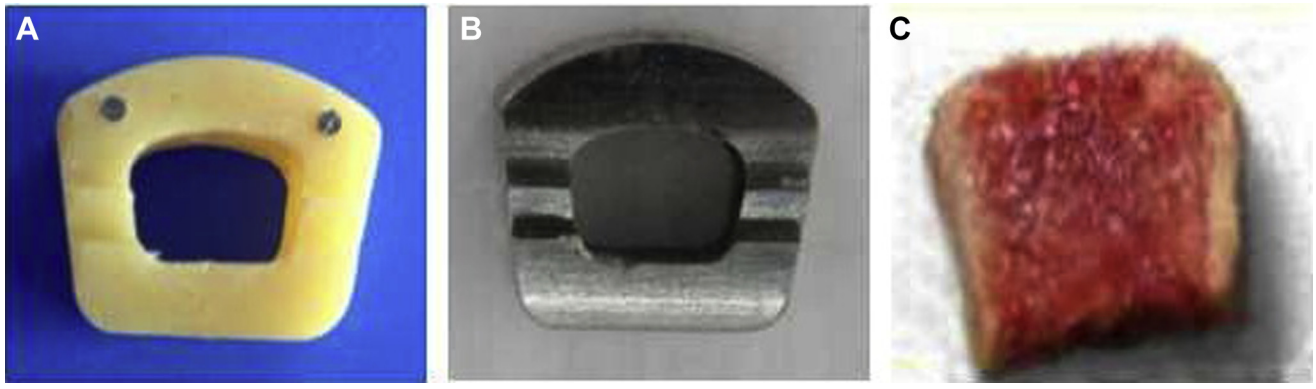

Figure 1. Implants tested in the present study. (**A**) Multiamino acid copolymer/nanohydroxyapatite/calcium sulfate (MAACP/n-HA/CS) cage, (**B**) titanium cage, and (**C**) autologous tricortical iliac crest bone graft, which was slightly different between goats.