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Case Report

Carbon Coated Implants as a New Solution for Metal Allergy in Early-Onset Scoliosis: A Case Report and Review of the Literature

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Abstract

Study Design: Retrospective case report.
Objective: To report the first known case of immunological camouflage of a metal spinal implant with carbon coating.
Summary of Background Data: Metal sensitivity is common and is a consideration when choosing orthopedic implants in susceptible individuals. The sensitivity often is to nickel, cobalt, or chromium, and titanium is used as a safe alternative. However, when the allergy is also to titanium, solutions may be much more difficult. This case describes an innovative solution to a complex metal allergy that includes titanium in a child requiring spinal instrumentation for early-onset scoliosis.
Methods: At age 6 years 7 months, the patient underwent an uncomplicated placement of bilateral posterior Vertical Expandable Prosthetic Titanium Ribs (VEPTRs; Synthes, Inc., West Chester, PA). At that time, there were no known metal allergies. At 3 weeks, the right side had become erythematous and had serosanguineous drainage. It briefly improved after each of 2 surgical debridements and a course of intravenous antibiotics, but within 6 weeks of the index procedure, the pain was still worsening. A titanium allergy was suspected and blood was sent for allergy testing. A test confirmed hypersensitivity to titanium, niobium, molybdenum, iron, and aluminum, among others. The remaining rod was removed. An in vivo trial for tolerance to high-grade stainless-steel implants was done. The implant was removed after 2 weeks because of systemic symptoms that occurred.
Results: A plasma-spray, carbon-coated VEPTR rod was designed. A rod sample was inserted into the patient's forearm for trial. After 3 months, there was no appreciable reaction. Carbon-coated VEPTRs were placed without complications. The patient has undergone multiple lengthening using the carbon-coated VEPTRs.
Conclusions: In the rare patient with multiple allergies, choosing orthopedic implants can be challenging. An innovative carbon coating was applied by plasma spray to the VEPTR system, with good results.

Keywords: Early-onset scoliosis; Metal allergies; VEPTR surgery; Carbon-coated implants

Introduction

Metal sensitivity is common and is a consideration when choosing orthopedic implants in susceptible individuals [1-3]. The sensitivity often is to nickel, cobalt, or chromium, and titanium is used as a safe alternative. However, when the allergy is also to titanium, solutions may be much more difficult [4,5]. This report describes an innovative solution to a complex metal allergy that includes titanium in a child requiring spinal instrumentation for early-onset scoliosis. The allergens, diagnostic course, and surgical solution are reviewed.

Materials and Methods

The patient was born with hypoplastic lungs, scoliosis, and respiratory difficulties suggestive of syndromic thoracic insufficiency. He presented to the senior author (JHP) at age 4 years 3 months with scoliosis measuring 47° right thoracic and 52° left lumbar, kyphosis of 115°, and no neurologic

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deficits. Consideration was given for Vertical Expandable Prosthetic Titanium Rib [VEPTR]; Synthes, Inc., West Chester, PA) placement to allow spinal curve stabilization and, it was hoped, salvage of pulmonary function. The child spent much of the next 2 years with gastrojejunostomy tube surgeries, management of respiratory infections, and cardiac and pulmonary optimization.

At age 6 years 7months, his pulmonary function had declined to a forced vital capacity (FVC) of 41% and forced expiratory volume (FEV1) of 46% compared with predicted normal for age despite maximal medical therapy. He underwent an uncomplicated placement of bilateral posterior VEPTRs (Figs. 1 and 2). At that time, there were no known metal allergies. Although the wound was clear and dry at 2-week follow-up, at 3 weeks the right side had become erythematous and had serosanguineous drainage. It briefly improved after each of 2 surgical debridements and a course of intravenous antibiotics, but within 6 weeks of the index procedure, the pain was still worsening. The wound remained erythematous; therefore, the right rod was removed and the patient was placed in a thoracolumbosacral orthosis for support. Final wound cultures were negative.

The wounds healed well and stopped draining, but the patient continued to have gastrointestinal discomfort and skin itching initially thought to be related to his history of multiple gastronomy feeding tube and jejunostomy feeding tube procedures. Four months after rod placement, the patient developed worsening chest pain, breathing difficulty, wheezing, and a pruritic eczematous rash, but no hives or erythema. A titanium allergy was suspected and blood was sent for allergy testing. A Melisa test (Memory Lymphocyte Immunostimulation Assay; Melisa Diagnostics, Stockholm, Sweden) confirmed hypersensitivity to titanium, niobium, molybdenum, iron, and aluminum, among others. This test is an in vitro blood analysis of type IV T cell–mediated delayed hypersensitivity to metals. Despite some improvement in chest and skin symptoms with oral steroids, the remaining rod was removed. Chest symptoms and itching immediately improved. Although a thoracolumbosacral orthosis was used, the curve worsened to 74° thoracic and 60° lumbar. Kyphosis also increased. Pulmonary function was 34% FEV1 and 35% FVC at the age of 7 years 4 months. As an in vivo trial for tolerance to high-grade stainless-steel implants, a small portion of a 4.5-mm stainless-steel rod (De Puy Co., Raynham, MA) was placed subcutaneously in the forearm. By 2 weeks postimplant, the skin became pruritic and erythematous. Asthma attacks increased. The implant was removed. Systemic symptoms resolved in a few days with the addition of oral antihistamine medication.

Consideration was given to surgical alternatives while curve progression and worsening pulmonary function continued. One of the more critical considerations of a new implant was the need for durability, hardness, and

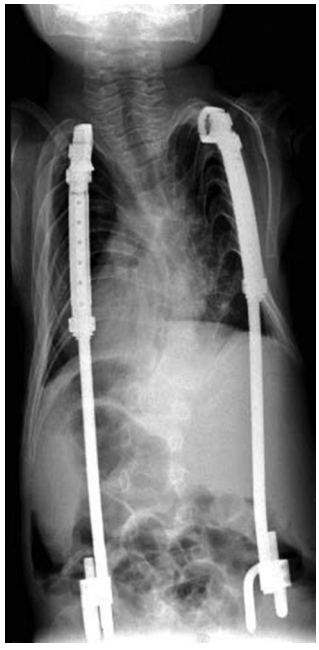

Fig. 1. Anteroposterior scoliosis X-ray immediately after initial noncoated Vertical Expandable Prosthetic Titanium Rib placement.

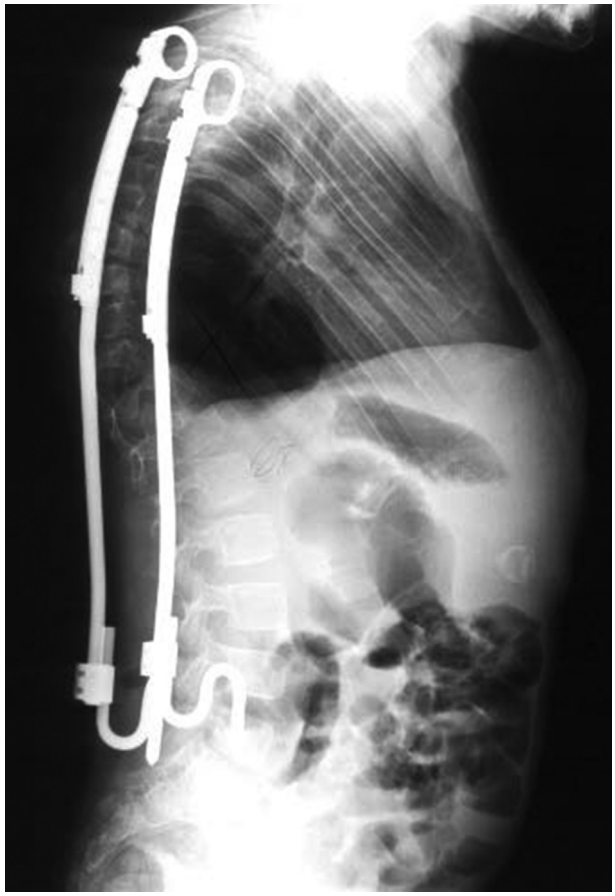

Fig 2. Lateral X-ray immediately after initial noncoated Vertical Expandable Prosthetic Titanium Rib placement.

maximum scratch resistance. The child would need to undergo multiple procedures over several years. Lengthening and retightening could cause deep scratches and release underlying ions and recurrent allergic manifestations.

Results

With help from company engineers, a plasma-spray carbon-coated VEPTR rod was designed. A rod sample was inserted into the patient's forearm for trial. After 3 months, there was no appreciable reaction. Carbon-coated VEPTRs (Figs. 3 and 4) were placed without complication after 2 weeks of preoperative halo gravity traction. A spine to rib construct was used because of pelvic pain after the initial surgery. Rubber-tipped instruments were used in placement to help minimize damage to the coating.

Several revision and lengthening surgeries have been performed since the index coated implant surgery at age 8. An intercurrent episode of nephrotic syndrome has been successfully treated with oral steroids and renal function is stable. To date, it has been 4 years since placement of the carbon-coated rods. The patient is essentially symptom-free except for the first week after each lengthening, when he had localized itching over the rods and a mild increase in wheezing, which was controlled with oral antihistamines. Symptoms resolved after that week. This reaction was presumed to result from local irritation caused by small amounts of titanium released at nicks in the coating during the lengthening.

Since placement of the carbon-coated rods, his pulmonary function has remained stable and the thoracic and lumbar curves have remained under control (Figs. 5 and 6) The last pulmonary function tests showed an FEV1 of 36% and FVC of 35%, 7 years 5 months after insertion of carbon-coated VEPTRS; these values remained stable since the surgery. The patient is now 12 years 9 months of age. A formal fusion is planned with carbon-coated implants in the near future.

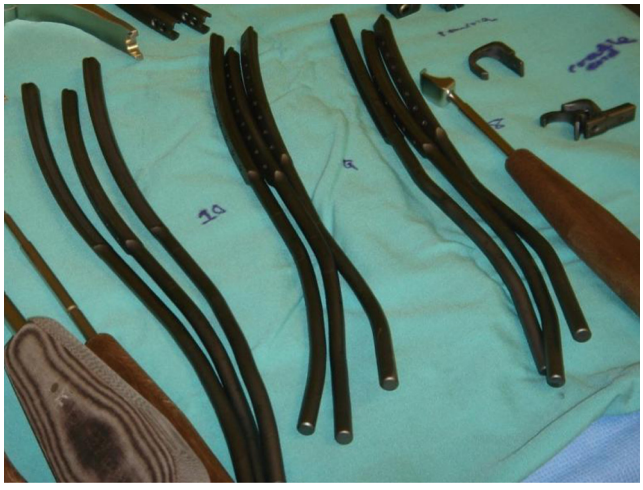

Fig. 3. Plasma-sprayed carbon-coated Vertical Expandable Prosthetic Titanium Rib system.

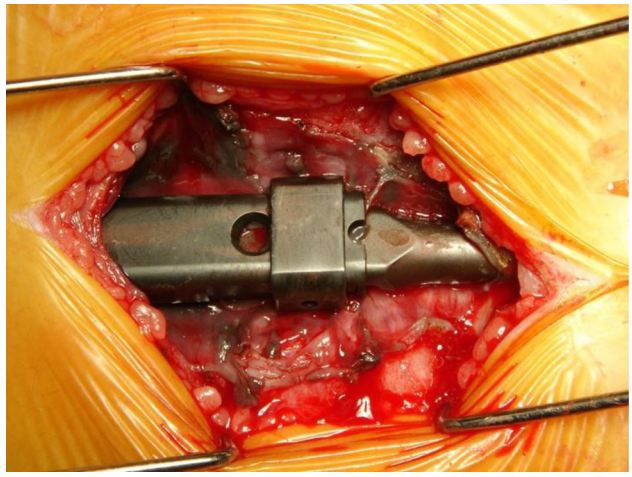

Fig. 4. Placement of carbon-coated Vertical Expandable Prosthetic Titanium Rib assembly.

Discussion

In some cases of early-onset scoliosis, respiratory insufficiency may be improved by VEPTRs [6], which allows controlled expansion of the thorax. A titanium strut is placed superiorly to a natural rib and inferiorly to a rib, lumbar spine, or sacral ala. The struts are then periodically

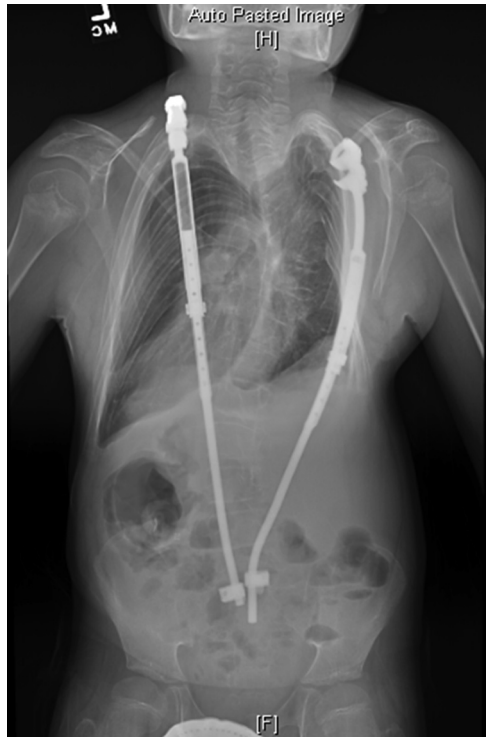

Fig. 5. Posteroanterior radiograph of carbon-coated implants in place, controlling scoliosis 4 years 10 months after implantation.

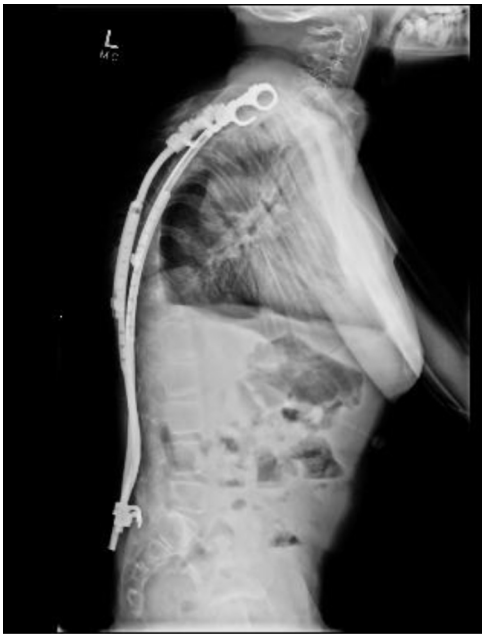

Fig. 6. Lateral radiograph of carbon-coated implants in place, controlling scoliosis 4 years 10 months after implantation.

lengthened at 6-month intervals via a sliding sleeve and locking clip to provide longitudinal and radial growth of the thorax and spine. Waldenhausen et al. [7] used 36 VEPTRs in 22 patients with thoracic insufficiency, with good results and decreased carbon dioxide retention. Two of those patients had Jeune syndrome; 1 needed a revision.

In the general population, contact dermatitis to metal has a high prevalence. Nickel allergies are most common and have been documented to be up to 17% in women and 3% in men in the United States. Cobalt and chromium follow behind, with 1% to 9% allergic response [1,11]. It has also been shown that patients with contact dermatitis or a cutaneous allergy may not have the same response to deep implants of the offending metal. Schuh et al. [2] reviewed 300 consecutive total hip and knee arthroplasty patients. They found that 13% of patients had an allergic response to cutaneous testing of the constituent materials or benzoyl peroxide, but only 1% of total patients had a reaction to the deep implant. The response included osteolysis, recurrent effusion, and/or eczema.

Swiontkowski et al. [3] studied the prevalence of metal sensitivity and conversion after fracture fixation. Skin patch testing of 493 trauma patients with no previous implants showed a sensitivity prevalence of 1.3% to nickel, 1.8% to cobalt, and 0.2% to chromium. Titanium response was not analyzed. The test was repeated a minimum 30 days after fixation. Conversion from a negative response to a positive occurred for 3.8% nickel, 3.8% cobalt, and 2.7% chromium. Of 56 patients with a patch test–positive response, 41 were available for at least a 3-month follow-up. No infections and 1 occurrence of broken screws were reported. The authors did not comment on respiratory or skin manifestations.

Titanium is often used in patients with nickel and cobalt chrome allergies. In its pure form, it is reported to be inert in the human body, immune to body fluid attack, and strong and flexible. However, there are patients such as ours who adversely react to even these metals. Titanium allergies have been shown to have 0.6% incidence in dental implant patients [4]. Symptoms ranging from nonspecific immune suppression to skin rash and implant failure were described. Overall, it is difficult to assess the prevalence of true titanium allergy because it is speculated that some of the reaction may be due to slight nickel impurities in the titanium [8]. A report from Germany recently recorded the incidence of titanium allergy in dental and other implants [5]. Removal of the implants was followed by resolution of symptoms, as in our case, and also reversal of the positive Melisa test.

Zirconium has also been used in patients with metal allergies. It is an inert, nonmetal ceramic with excellent wear and strength properties [9,10]. Studies have shown improved resistance properties and a significant decrease in third-body wear compared with cobalt chrome knee arthroplasty implants [11,12].

In wear simulation tests, Reich et al. [13] showed a 60% wear rate reduction and a significant decrease in metal ion release with a proprietary multilayer technique for coating knee implants for patients allergic to nickel, cobalt, or chromium. Lützner et al. [14] proposed a 7-layer zirconium coating over standard cobalt-chrome total knee implants to reduce metal ion release. Popoola et al. [15] patented a method for depositing zirconium onto an orthopedic implant. Yang et al. [16] analyzed a plasma-spayed zirconium interface to titanium and cobalt-chrome with X-ray diffraction and scanning electron microscopy, examining physical characteristics, surface roughness, hardness, and adhesive strength. Scanning electron microscope analysis showed a rough, porous, melted interface between the zirconium and its substrate; acid etching created small gaps in the interface between the zirconium and titanium. However, no studies could be found that tested the ability of zirconium or zirconium-coated spinal rods to withstand the contouring and lengthening procedures performed in scoliosis and VEPTR cases. Consideration was given to using zirconium rods in this case, but implant brittleness and inability to contour the implant preoperatively were thought to preclude its use.

Other studies have been done to test surface-coated implants, but these were for improving surface–tissue interface rather than allergen minimization. Gollwiter et al. [17] tested coronary artery stents coated with poly-D,L-lactic acid for mechanical wear during lengthening in rat and human cadaver models. The devices tolerated 8% of lengthening before microcracking and cohesive failure of the coating. The researchers found that the coating did not influence T-cell reactivity toward the coating material (poly-D,L-lactic acid); however, the study was not designed to test allergic response to the original implant material. That

biodegradable coating would not provide the time durability needed for the current authors' application. A biocompatibility study of carbon coating of osteocytes was published in 2007 [18].

In the rare patient with multiple metal allergies, including titanium, choosing orthopedic implants can be challenging. There is a lack of published information on these cases, particularly with regard to spinal surgery. This article presents the case of a child with syndromic scoliosis whose thoracic insufficiency and scoliosis treatment was complicated by multiple metal allergies. An innovative carbon coating was applied by plasma spray to the VEPTR system, with good results after 4.5 years' follow-up. The authors believe this to be the first report of carbon-coated implants used in scoliosis surgery. Further use of carbon coated implants is planned in this case for definitive posterior spinal fusion.

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References

[1] Thyssen JP, Menné T. Metal allergy—a review on exposures, penetration, genetics, prevalence, and clinical implications. *Chem Res Toxicol* 2010;23:309−18.
[2] Schuh A, Lill C, Hönle W, Effenberger H. Prevalence of allergic reactions to implant materials in total hip and knee arthroplasty. *ZentralblChir* 2008;133:292−6.
[3] Swiontkowski MF, Agel J, Schwappach J, et al. Cutaneous metal sensitivity in patients with orthopaedic injuries. *J Orthop Trauma* 2001;15:86−9.
[4] Sicilia A, Cuesta S, Coma G, et al. Titanium allergy in dental implant patients: a clinical study on 1500 consecutive patients. *Clin Oral Implants Res* 2008;19:823−35.
[5] Muller KE, Valentin-Thon E. Hypersensitivity titanium: clinical and laboratory evidence. *Neuroendocrinol Lett* 2006;(Suppl 1):31−5.
[6] Campbell RM. Spine deformities in rare congenital syndromes. *Spine (Phila Pa 1976)* 2009;34:1815−27.
[7] Waldhausen JH, Redding GJ, Song KM. Vertical expandable prosthetic titanium rib for thoracic insufficiency syndrome: a new method to treat an old problem. *J Pediatr Surg* 2007;42:76−80.
[8] Forte G, Petrucci F, Bocca B. Metal allergens of growing significance: epidemiology, immunotoxicology, strategies for testing and prevention. *Inflamm Allergy Drug Targets* 2008;7:145−62.
[9] Manicone PF, Rossi Iommetti P, Raffaelli L. An overview of Zirconia ceramics: basic properties and clinical applications. *J Dent* 2007;35:819−26.
[10] Piconi C, Maccauro G. Zirconia as a ceramic biomaterial. *Biomaterials* 1999;20:1−25.
[11] Galetz MC, Fleischmann EW, Konrad CH, et al. Abrasion resistance of oxidized zirconium in comparison with CoCrMo and titanium nitride coatings for artificial knee joints. *J Biomed Mater Res B Appl Biomater* 2010;93:244−51.
[12] Heyse TJ, Chen DX, Kelly N, et al. Matched-pair total knee arthroplasty retrieval analysis: oxidized zirconium vs. CoCrMo. *Knee* 2011;18:448−52.
[13] Reich J, Hovy L, Lindenmaier HL, et al. Preclinical evaluation of coated knee implants for allergic patients. *Orthopade* 2010;39:495−502.
[14] Lützner J, Dinnebier G, Hartmann A, et al. Study rationale and protocol: prospective randomized comparison of metal ion concentrations in the patient's plasma after implantation of coated and uncoated total knee prostheses. *BMC Musculoskel Disord* 2009;10:128.
[15] Popoola O, Anderson JP, Hawkins ME, et al. Method for producing a Zirconia-layered orthopedic implant component. Warsaw, IN: Zimmer Technology, Inc. US patent 7790216.
[16] Yang Y, Ong JL, Tian J. Deposition of highly adhesive ZrO(2) coating on Ti and CoCrMo implant materials using plasma spraying. *Biomaterials* 2003;24:619−27.
[17] Gollwitzer H, Thomas P, Diehl P, et al. Biomechanical and allergological characteristics of a biodegradable poly(D, L-lactic acid) coating for orthopaedic implants. *J Orthop Res* 2005;23:802−9.
[18] Thorwarth G, Saldamli B, Schwarz F, et al. Biocompatibility of doped diamond-like carbon coatings for medical implants. *Plasma Processes Polym* 2007;4:S364−8.