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Chronology of the Radiographic Appearances of the Calcium Sulfate-Calcium Phosphate Synthetic Bone Graft Composite Following Resection of Bone Tumors: A Follow-up Study of Postoperative Appearances

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Abstract

Purpose: The objective of the study was to characterize the radiographic appearance of graft resorption and new bone incorporation into a postresection defect of the calcium-sulfate calcium-phosphate synthetic bone graft composite following resection of benign bone tumours.
Methods: Twenty-five patients who underwent treatment with the $CaSO_4/CaPO_4$ synthetic graft following bone tumour resection were retrospectively identified from our oncology database. Postoperative radiographs were assessed for: 1) combined partial graft resorption and ingrowth at the graft site; 2) complete graft resorption with complete incorporation of new bone into the defect. After chronologically grouping radiographs, the volume of graft material used to fill bony defects, radiographic evidence of complications, and patterns of resorption were recorded.
Results: Partial resorption of graft material/partial ingrowth of new bone was seen in 21 patients at 2.5 months postoperatively. Complete resorption of graft with complete new bone incorporation at the graft site was seen in 94% of cases (15 of 16) by 10 months after surgery. Mean time to complete incorporation of new bone was 6.7 months. Time to resorption of the graft with new bone ingrowth was found to be related to the volume of graft used with smaller volumes showing earlier resorption. For all cases demonstrating resorption (21 of 21), the pattern observed was peripheral to central. Five patients developed complications, including tumour recurrence, cyst formation, and graft site infection.
Conclusion: Our study suggests a characteristic time and volume related radiographic pattern of resorption and new bone ingrowth with the $CaSO_4/CaPO_4$ synthetic graft. Findings that deviate from this pattern may represent complication and warrant additional follow-up.

Résumé

Objet : L'étude avait pour objectif de caractériser la résorption du substitut osseux (composite synthétique à base de sulfate de calcium et de phosphate de calcium ayant été utilisé pour combler la perte de substance osseuse) ainsi que l'intégration du nouveau tissu osseux à la suite d'une résection de tumeurs osseuses bénignes.
Méthodes : Notre base de données en oncologie a permis d'identifier, de façon rétrospective, 25 patients ayant reçu un traitement par greffon synthétique à base de sulfate de calcium et de phosphate de calcium à la suite de la résection d'une tumeur osseuse. Les radiographies réalisées après la chirurgie ont été examinées afin d'évaluer 1) la résorption partielle du greffon et l'interposition au site de greffe combinées; 2) la résorption complète du greffon et l'intégration complète du nouveau tissu osseux dans la zone de comblement. Une fois les

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radiographies regroupées de façon chronologique, nous avons relevé le volume de substitut osseux nécessaire au comblement du déficit, les signes radiographiques de complication et les schémas de résorption.
Résultats : Une résorption partielle du substitut osseux ou une interposition partielle de nouveau tissu osseux a été observée chez 21 patients, 2,5 mois après la chirurgie. Par ailleurs, une résorption complète du greffon avec intégration complète du nouveau tissu osseux au site de greffe a été observée chez 15 des 16 patients (94 % des cas) de 10 mois après la chirurgie. L'intervalle moyen pour une intégration complète du nouveau tissu osseux a été établi à 6,7 mois. Nous avons constaté que l'intervalle nécessaire à la résorption du greffon et à l'interposition du nouveau tissu osseux était lié au volume de substitut utilisé: un volume moindre correspondant à une résorption plus rapide. Chez les 21 patients présentant une résorption, le processus a semblé s'opérer de façon concentrique (de la périphérie vers le centre). Cinq patients ont présenté des complications, notamment une récurrence de la tumeur, une formation de kyste ou une infection au site de greffe.
Conclusion : Sur le plan radiographique, l'étude révèle une corrélation entre l'intervalle de résorption du greffon et d'interposition du nouveau tissu osseux, et le volume de substitut osseux à base de sulfate de calcium et de phosphate de calcium utilisé à des fins de comblement. Les résultats non conformes à ce schéma peuvent signaler des complications et exiger des mesures de suivi supplémentaires.

Key Words: Synthetic bone graft; Musculoskeletal; Benign bone tumour

Synthetic bone graft substitutes are becoming increasingly popular for the reconstruction of cavitary defects following intralesional curretage of benign primary bone tumours [1]. Although autograft bone is osteoconductive, osteoinductive, and osteogenic, its supply is limited and its use is associated with chronic pain, donor site infection, iatrogenic fracture, and poor cosmesis [2]. Allograft bone is osteoconductive, and may be osteoinductive depending on its processing, but its use is associated with disease transmission, deep infection, and poor union rate [2]. Synthetic bone graft substitutes avoid these limitations by serving as an osteoconductive scaffold across which surrounding normal bone can heal [2].

PRO-DENSE (Wright Medical Technology, Memphis, TN), is a ceramic-based synthetic bone graft comprised of a composite calcium sulfate-calcium phosphate ($CaSO_4$/$CaPO_4$) matrix mixed with beta-tricalcium phosphate (β-TCP) granules. Its $CaSO_4$ component quickly undergoes dissolution, which initiates rapid bony ingrowth [3], while its $CaPO_4$ component and β-TCP granules provide a lasting structure to support complete osseous integration [4,5]. Initial reports have demonstrated its clinical utility in the management of primary benign bone tumours [6−8].

Clinically, knowledge of the normal pattern and timing of PRO-DENSE resorption and osseous integration is essential. In order to discriminate postoperative complications and tumour recurrences from successful graft incorporation, and to guide functional rehabilitation after surgery, radiologists and orthopaedic surgeons must understand this composite's natural history. Our preliminary radiological series demonstrated partial resorption as early as a few weeks postoperatively, visualized as a peripheral radiolucency surrounded by a circumferential shell of radiodense osseous ingrowth. This pattern then progressed inwards centripetally, typically completing by 6 months for smaller defects and 1 year for larger defects [6].

In this study, we expand the size and follow-up of our series to further clarify the chronology of the radiographic appearances of the calcium sulfate-calcium phosphate synthetic bone graft composite following resection of bone tumours and the normal pattern of PRO-DENSE incorporation. We specifically report the usual timing and pattern of partial and complete resorption, and we investigate the relationship between volume of PRO-DENSE and timing. We also demonstrate the appearance of tumour recurrence.

Materials and Methods

This study received ethics approval from the McMaster University/Hamilton Health Sciences Research Ethics Board (REB# 12-388-C). Throughout this article we refer to the ceramic-based synthetic bone graft of calcium sulfate-calcium phosphate ($CaSO_4$/$CaPO_4$) matrix and beta-tricalcium phosphate (β-TCP) granules as PRO-DENSE; however, this was not industry sponsored research.

Using our institutional orthopaedic oncology database, all patients that underwent resection of primary benign bone tumours followed by reconstruction with PRO-DENSE from July 2007 to August 2012 were identified. The multimodality imaging features in one of the patients' were suggestive of a proximal tibial enchondroma; however, the pathology came back as a low grade chondrosarcoma. Given its low malignant potential, this case was therefore included in our case series.

Each patient had follow-up imaging but there was no standardization of time intervals at which these occurred. We categorized the follow-up plain radiographs into groups with time intervals of less than 5 days, 1-3 months, 3-6 months, 6-12 months, 12-24 months, and greater than 2 years postoperatively following the index procedure.

Radiographs were performed using a Siemens Radiography system (Vertex and Multex model; Siemens, Erlangen, Germany). Two independent fellowship-trained musculoskeletal radiologists retrospectively interpreted all radiographs to determine partial and complete resorption, and evidence of complications. Differences in interpretation were resolved by consensus. There were 2 cases (patient #10 and #20; Table 1) where the readers had differences in interpretation on the initial follow-up radiographs obtained in the 3