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Vascular bundle transplantation combined with porous bone substituted scaffold for the treatment of early-stage avascular necrosis of femoral head

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ABSTRACT

Various reasons leading to disruption of blood supply will result in avascular femoral head necrosis. Decompression of lesion area, structural support to subchondral bone, and rebuilding of blood supply system are the keys for a successful hip preserve surgery. Reconstruction of local vascular network is always a huge challenge in clinical. Based on tantalum rod implantation and free vascularized fibular grafting, we propose the combined application of vascular bundle transplantation and porous bone substitute scaffold implantation as a potential novel treatment method. It may simultaneously achieve decompression, support and blood supply reconstruction. The hypothesis provides some new ideals and possibilities for solving this clinical problem of femoral head necrosis.

Introduction

Avascular necrosis of femoral head mainly caused by the disruption of blood supply in the femoral head due to various reasons. It usually occurs in young people aged between 20 and 50 and its prevalence is increased in recent years [1,2]. Total hip replacement cannot bring long-term satisfactory result in this relatively active population because of wear and loosening. A variety of hip preserve surgeries (core decompression, femoral osteotomy, autologous or allogeneic bone-grafting, bone substitute scaffold such as tantalum rod, and vascularized bone-grafting) are applied in clinical practice [1,3–5], but their effectiveness are still controversial since none of them can ensure a successful reconstruction of the blood supply in the femoral head. In general, decompression of the lesion area, structural support and establishment of microcirculation are the three key elements to the hip preserve surgery. Many techniques can achieve decompression and structural support, while cannot rebuild blood supply. For instances, the long-term effect of tantalum rod implantation, whose early clinical result was reported to be good, is unsatisfactory, because it is failed to promote the reconstruction of local vascular network [6–8].

Hypothesis

Based on tantalum rod implantation and free vascularized fibular grafting, we propose that the combined application of vascular bundle transplantation and porous bone substitute scaffold may be a potential novel hip preserve treatment method for early-stage avascular necrosis of femoral head. The porous scaffold (designed by Beijing Shapedream Information Technology Co., Ltd.) (Fig. 1) is designed with a U-shaped tunnel as vessel carrier. Firstly, transplanted vascular bundle, such as great saphenous vein, passes through the U-shaped tunnel in the scaffold, porous tantalum or titanium scaffold for example. Then, porous scaffold with the transplanted vascular bundle is implanted into core decompression channel in the femoral neck and head. Finally, the two ends of vascular bundle are anastomosed to lateral circumflex femoral artery and vein (Fig. 1). The scaffold implantation will achieve decompression and structural support. The transplanted vascular bundle can well reconstruct the local microcirculation system. The improvement of blood supply will further enhance the bone regeneration and repair. This study is expected to provide some new possibilities for solving the clinical problem of femoral head necrosis.

Evidence of the hypothesis

Porous bone substitute scaffold implantation provides structural support and allows the ingrowth of bone and blood vessel.

After removing necrotic lesion by drilling, porous bone substitute scaffold, such as porous tantalum or titanium rod, can be implanted into the core decompression tunnel to provide structural support [6,9]. Decreasing of intramedullary pressure after core decompression will alleviate the patient's pain. Support for subchondral bone provided by the implanted scaffold will prevent collapse of the femoral head. Both

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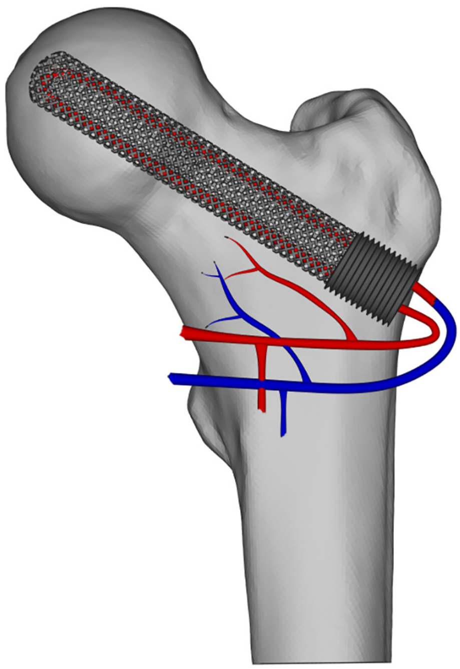

Fig. 1. Vascular bundle transplantation combined with porous bone substituted scaffold for the treatment of femoral head necrosis.

porous tantalum and titanium rods show satisfactory early clinical results. The porous structure is conducive to ingrowth of bone and blood vessels. However, the lack of additional blood supply sources inhibits bone tissue from growing into the deep portion of bone substitute scaffold. Tanzer et al reported that the average extent of bone ingrowth was only 1.9% in the failed tantalum rod cases [8].

Vascular bundle transplantation enables vascularization in an ischemic environment and enhances bone regeneration and repair.

Many studies have well proven that the disruption of blood supply is detrimental to bone regeneration and the improvement of local microcirculation will enhance bone formation [10–15]. Various strategies have been used to promote angiogenesis in an ischemic environment. Among them, vascular bundle transplantation is particularly suitable for promoting vascularization of large-scale bone substitute scaffold and large bone defect [16]. It can successfully establish a new vascular network in an ischemic environment, such as avascular necrosis area in the femoral head. Previous studies showed that, after the implantation of arteriovenous bundle in the central tunnel of a 3D-printed PLGA/β-TCP scaffold, osteogenesis and angiogenesis are both enhanced [16]. Similarly, the insertion of deep femoral artery and vein into a β-TCP tissue-engineered bone graft was proven to promote vascularization and bone regeneration in a femoral bone defect model [17]. Hypoxia, as one of the most potent initiators of angiogenesis, in an ischemic environment can promote the implanted vascular bundles to grow lateral branches and to establish an effective local microcirculatory system [16–19]. The implanted vascular bundle can improve oxygen and nutrients supply, provide osteogenic and angiogenic growth factors, and recruit stem cells needed for lesion repair.

Discussion

Feasibility of the proposed treatment method

This hypothesis is proposed based on tantalum rod implantation [6,7] and free vascularized fibular grafting technique [20,21]. The procedures can also refer to them. The porous scaffold is designed with a U-shaped tunnel as vessel carrier. Firstly, core decompression to remove necrotic bone by drilling. Secondly, vascular bundle is inserted into the U-shaped tunnel in the scaffold. Then, the porous scaffold with vessels will be implanted into the core decompression channel. Finally, the two ends of vessels are anastomosed to lateral circumflex femoral artery and vein.

The porous bone substitute scaffold can be made of tantalum, titanium or biodegradable materials. Anticoagulant and vasodilator drugs need to be used regularly to avoid embolization. However, there is still a lot of work should be done to optimize design of the scaffold and to verify its effectiveness in large animal models before clinical application.

Conclusion

This proposed treatment method has the potential to simultaneously provide decompression of lesion area, structural support to subchondral bone, and successful reconstruction of new vascular network in the femoral head. It has the potential to solve the clinical problem of femoral head necrosis.

Declaration of Competing Interest

None declared.

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