Reconstruction of large critical sized segmental diaphyseal bone defects with degradable and non-degradable materials

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Materials and Methods: In the femur of 24 goats a large segmental critical sized diaphyseal bone defect was created after performing a lateral exposure and a double osteotomy. The defect was stabilized using an intramedullary nail and reconstructed with a structural cortical autograft preserving the periosteum (6 goats: control group). In a second group (n = 6) the defect was reconstructed with a titanium cage filled with firmly impacted morsellized autograft with preservation of the periosteum. In the third and fourth groups (n = 6) the defect was reconstructed using a Tantalum trabecular metal cylinder with or without preserving of the periosteum, respectively.

Radiological analysis was performed at 0, 12 and 26 weeks follow up. After 6 months the reconstructions were tested mechanically (torsion strength to failure in N) and by histology (non-decalcified histology).

All operated groups were compared on torsional strength amongst each other and with the contralateral healthy bone. The data were statistically analyzed using a students t-test with a significance level of p<0.05.

Results: The clinical performance of all reconstructions was adequate allowing unlimited weight bearing. Radiological all massive cortical bone grafts, cages filled with morsellized graft and all Tantalum trabecular metal cylinders with periosteum coverage united with the host bone. The reconstructions with the Tantalum cylinder without periosteum coverage lead to radiological non-union in 5 cases and in one case to a union. Mechanical torsion strength of the structural cortical graft reconstruction was 60.3 % as compared to the contralateral (non-operated) femur after six months. Torsion strength of the femur with the cage reconstruction was 66.6 % as compared to the contralateral femur. Mechanical torsion strength of the femur with a Tantalum trabecular metal cylinder and periosteum preservation was 102.1 % as compared to the contra lateral femur after six months. Torsion strength of the Tantalum cylinder in the periosteum absent reconstruction was 24.5 % as compared to the contra lateral femur. Histological in the cortical bone of the autograft creeping substitution was found which had lead to new vital osteons embedded in the necrotic remnants of the devitalized necrotic autograft. The bone was surrounded by periosteal apposition. The cage group showed viable bone in and around the cage and only a few and always incorporated remnants of the bone grafts were found. Histological the Tantalum cylinders with periosteum coverage revealed considerable ingrowth of bone at the ends and superficial along the surface of the whole implant. The Tantalum cylinders without periosteum coverage revealed fibrous tissue formation around and in the implants, with a complete lack of bone ingrowth in 5 cases. In one case bone ingrowth was observed similar as in the periosteum preserved group.

Discussion: A histological study of massive human allograft, retrieved from two to 156 months after implantation showed that repair of the necrotic graft matrix was limited to a thin layer both periosteally and endosteally. External repair consisted of the apposition of a thin seam of host bone on the outer surface of the graft. Internal repair was confined to the ends of the cortices and penetrated so slowly that only 15% to 20% of the graft was repaired by five years [5]. In our animal in which we reconstructed the defect with impacted cancellous bone chips complete remodeling was observed after 26 weeks but the strength was not equal to the contralateral intact bone. The reconstruction of segmental diaphyseal bone defects using a cage with a morsellized graft had better mechanical and biological characteristics compared to a structural cortical graft although the difference was not significant. The cage and morsellized graft have an open structure to promote ingrowth. The remodeling process however was not completed after 6 months. The morsellized graft obtained sufficient initial mechanical features due to combination of impaction, and containment in a cage. The reconstruction of segmental diaphyseal bone defects using a Tantalum trabecular metal cylinder and periosteum preservation fulfilled this goal by restoring strength to the level of the contralateral non-operated side after 6 months.

The nonunions in the defect reconstructions in our study can be the result of a combination of movement in the reconstruction caused by an intramedullary nail and the lack of fixation of the cylinder by external callus, which is diminished due to the resection of the periosteum.

In summary, a cage filled with a morsellized graft and a Tantalum cylinder can be considered as an alternative for a massive cortical graft in the reconstruction of large critical sized diaphyseal bone defect with the periosteum in situ. In absence of the periosteum a reconstruction with a Tantalum cylinder and an intramedullary nail leads to poor results.