INTRODUCTION:Bone represents a tissue in constant remodeling. Osteoclasts are
known to catalyze bone matrix, while osteoblasts secrete new bone
matrix directly apposed to the original one. Following surgical trauma or
presence of foreign bodies for example, bone defense mechanisms have
either a temporary or definitive impact on bone remodeling. In turn, any
change in the formation/resorption couple will lead to important
consequences such as the loss of bone structure integrity for example
[1]. In this study, two types of metallic intervertebral lumbar fusion
implants were studied in a lumbar sheep model in order to evaluate bone
bridging, osseointegration, and structural change induced in the
peripheral tissue mass after 3, 6 and 12 months post-implantation.

MATERIALS AND METHODS:
Experimental design and surgical technique:
Mature female sheep (1-2 years old) simultaneously underwent 2
level interbody surgeries (retroperitoneal approach; left lumbar regions
L2-L3 and L4-L5) with one ungrafted porous nitinol (PNT) implant
(φ1×20mm, 230±130µm pores, 65±5% porosity; Actipore®, Biorthex
Inc., Montreal, QC, Canada) and one hollow threaded TiAlV fusion cage
(φ1×20mm; BAK®, Sulzer Spine-Tech Inc., Minneapolis, MN, USA).
The TiAlV cage was first filled with iliac crest bone chips, then screwed
into position using a slightly modified posterior lumbar interbody fusion
(PLIF) instrumentation. The PNT implant was inserted in the second
intervertebral space in absence of autograft seeding. The wound was
closed in layers and sheep were allowed to recover for 3, 6, and 12
months following interbody surgery (4-6 sheep/time point). Animal care
complied with the Canadian Council on Animal Care (CCAC)
guidelines for care and use of experimental animals.

Evaluation protocol:
Necropsy and tissue harvest: Spinal columns were removed as units
(L1-L6), placed in neutral formalin (10%), and prepared for ground
sectioning. After fixation, L2-L3 and L4-L5 segments were isolated.
Implants were sectioned at increments of 5mm. Following trimming,
specimens were dehydrated in ethanol and cleared with xylene.
Undecalciﬁed tissues were then embedded in methylmethacrylate for 3
weeks. 100 to 300-µm sections were taken using an EXAKT saw and
ground to 60µm. Each section was then stained with Stevenel’s blue
(soft tissue) and van Gieson’s picrofuchsin (bone tissue) [2,3].

Macroscopic analysis: A thorough macroscopic analysis was
performed on histological slides using a digital camera (Nikon Model E
950). Direct contact of bone matrix to the implant was the criterion
chosen for complete bone fusion. Incomplete fusion was represented by
a mix of both hard and soft tissue at the implant periphery. Absence of
bone fusion was designated by the sole presence of soft tissue peripheral
to the implant.

Microscopic analysis: Structural change at implant periphery was
evaluated using transmitted light microscopy (Leica DM LP, ×400).
Statistical analysis: Univariate analyses using chi-square and Fisher
exact tests were performed to determine if any statistically significant
difference existed between lumbar implants

RESULTS:
The majority of PNT samples (15/16, 93.75%, Table 1) demonstrated
bone integration and apposition, whereas only 4 out of 16 TiAlV
implants (25.0%, Table 1) were shown to offer complete bone fusion.
PNT bone bridging at 3 and 6 months was signiﬁcantly superior
compared to TiAlV materials (p=0.05); the difference was not
statistically significant at 12 months (Fig. 1).
Periperal to the PNT implant, a microscopic analysis revealed the
presence of either osteoblasts or soft tissue ﬁbers. The latter were
speciﬁcally oriented perpendicularly to the surface regardless of
implantation time (Fig. 2a). Osteoblasts were observed to actively
synthesize bone matrix. The TiAlV materials were surrounded by soft
tissue, chondrocytes, and osteoclasts. Fibrous tissue ﬁbers showed a
parallel disposition to the TiAlV implant surface at 3 months (Fig. 2b),
with their orientation slowly evolving to a perpendicular one starting at 6
months (Fig. 2c) and completing at 12 months post-instrumentation (Fig.
2d) leading to an effective osseointegration.

DISCUSSION:
Bone matrix formation was observed in presence of porous nitinol
implants due to important osteoblastic activity necessary for osteoid
formation (Fig. 1a). In the case of TiAlV, bone resorption and
endochondral calcification were however observed peripheral to the
implants (Fig. 1b). It is possibly the result of a lack of biofunctionality,
since threaded TiAlV fusion cages do not possess microporosity features.
In turn, it is hypothesized that soft tissue inﬂuences bone integration:
bone progenitor cells may migrate following fiber orientation. Indeed, as
opposed to a parallel disposition of ﬁbers (TiAlV, 3-6 months., Fig. 2b-
c), osseointegration tends to be favored when ﬁbrous tissue is
perpendicular to the implant (PNT, 312 months, Fig 2a; TiAlV, 12
months only, Fig. 2d). Whereas non-porous materials tend to favor
parallel orientation, a porous material such as porous nitinol has
therefore initiated a perpendicular disposition of soft tissue ﬁbers, which is
followed eventually by osteoblast colonization and bone matrix
secretion in order to achieve rapid osseointegration.

REFERENCES: