Introduction: Progressive deformity correction is commonly applied to limbs. Its main advantage is that a small force can be used to safely and slowly overcome the visco-elastic properties of biological tissues. The authors realized that super-elasticity, a property of nickel-titanium (NiTi) shape memory alloy, may be useful in overcoming this problem, as it produces a constant recovery force for deformations within the range 8%. Use scoliosis correction as for example. Current scoliosis surgery rarely achieves full correction due to visco-elastic properties of spinal tissues. Use of excessive force in attempting a full correction may result in bony fractures or neurological deficit due to spinal cord damage. Our new correction approach is to establish a correction force over the scoliotic spine that may not completely straighten the deformity at the time of operation, but will apply a constant and predictable correction force following surgery, allowing progressive and continuous correction of the deformity without inducing neurological problems or compromise of the implant-bone interface. NiTi rods can be made maximally super-elastic at body temperature and malleable at room temperature [1]. This study aims to demonstrate in a goat model that these NiTi rods can be used as an internal fixator to safely overcome the viscoelastic properties of the spine and gradually change the spinal curvature.

Methodology: Five Capra species goats (4M and 1F) with an average age of 1.4 ± 0.4 years old were used in this study. Their average weight was 34.2 ± 3.9 Kg. No abnormality or neurological deficit was observed by physical examination. Pre-operative radiography indicated that all of their spines were healthy and without deformity (Fig. 1A). Heat treatment protocol [2] developed by our own was applied to the NiTi spinal rods to introduce the super-elastic property to the rods at 38°C, the body temperature of the goat. At the time of operation, lumbar spine segments of 5 goats were exposed posteriorly. A heat treated and pre-contoured super-elastic rod, with a coronal curvature of 60°, was first cooled to 20°C (malleable at this temperature), straightened and then implanted. After implantation, the rods were warmed to body temperature and the rate of scoliosis development initially observed clinically, and then after wound closure by daily radiographs. Curves were measured by using a common method in spinal deformity called Cobb’s measurement. Additionally, daily physical examination to detect any neurological deficit was carried out for each goat after operation.

Results: For example, in goat #1, we observed that only a 15° curve was induced immediately after surgery. Spinal deformity developed to 30° by 3 days (Fig. 1B), and progressed to 45° by 1 week (Fig. 1C). In general, all five goats had developed spinal deformity within a week after operation as shown in Fig. 2. The first two animals had developed neurological deficit the latter three did not find any neurological problem after performing facetectomy at lumbar region.

Discussion and conclusion: The results demonstrated that super-elastic rods can be used to progressively create spinal deformity. The reverse should also be true, and their use should allow a progressive and more complete correction of spinal deformities. Neurological deficit was never seen immediate after operation in any of the animals. However, the first two goats, which did not undergo facetectomy, developed paraplegia few days after operation. It is suggested the spinal cord is under compression and/or distraction as the severe scoliosis develops. In accordance with the literature [3], the lateral flexibility and range of motion (ROM) of the goat lumbar spine is very limited. To tackle with this problem, we performed facetectomy at lumbar region to compensate for the inadequate flexibility and ROM. Thereafter, neither paraplegia nor other neurological deficit were not found. In future clinical applications, this neurological problem is unlikely to occur in human patients with spinal deformity, as the model we used is to create spinal deformity. A sudden change into contour between the rod and the spine will not occur in patients where a deformed curve is being corrected. Moreover, the lateral flexibility of the human lumbar spine is much higher than that of the goat [3]. Rather than being a cause for concern, the onset of paraplegia demonstrates the power of the progressive correction system. Additionally, previous concerns with Ni release by NiTi alloys have been tackled by recent advances in nanotechnology surface treatment described by the authors [4]. A new generation of super-elastic spinal implants will help improve safety and efficacy of spinal deformity surgery as well as to other limb deformity surgeries.