A PAPER ON DESIGN AND ANALYSIS OF INTRAMEDULLARY NAIL

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ABSTRACT

Fracture history was regarded as significant if the child had sustained a vertebral fracture, or repeated long-bone fractures (2 fractures before age 10 years or at least 3 fractures before age 16 years) resulting from low-energy trauma. Skeletal health was evaluated with DXA, biochemistry, and radiographs, and life-style factor data were collected by interview; age- and sex-matched controls were used to assess predisposing factors. The accuracy of VFA, the visibility and detection rate of compressed vertebrae, was assessed in 65 children; standard radiographs were used for comparison. Transiliac bone biopsy was performed on 24 children with suspected primary osteoporosis based on frequent fractures and/or low BMD. Analysis of bone histomorphometry was performed using undecalcified samples. Histomorphometric findings were correlated with clinical data, and biochemical, radiographic, and densitometricfindings.

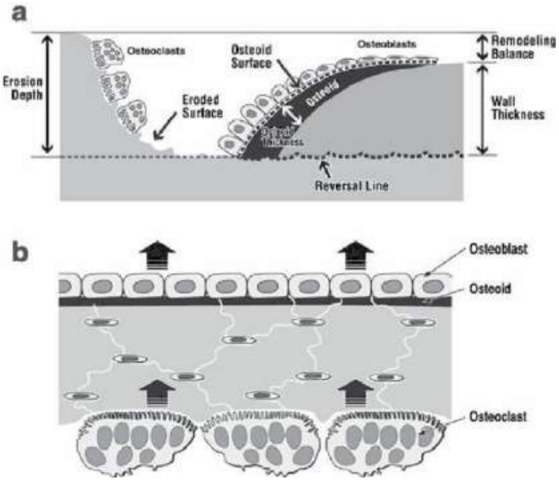
INTRODUCTION

A study about relatively new joining process of fractured bones using intramedullary nails with various tests for its design.

BONES AND FRACTURES

Bone is a dynamic tissue, which remodels and repairs itself throughout life. The many diverse structural and metabolic functions of bone are principally driven by the interplay between just two cell types: osteoblast and osteoclast. Osteoblasts are responsible for the production of the bone matrix constituents and new bone. They originate from multipotentmesenchymal stem cells, which have the capacity to differentiate into osteoblasts, adipocytes (fat cells), chondrocytes (cartilage-forming cells), myoblasts (muscle cells) or fibroblasts (Hadjidakis et al. 2006). Osteoblasts initially produce osteoid by depositing collagen, and then initiate the mineralization by providing the enzymes required (e.g., alkaline phosphatase and osteocalcin).

The longitudinal growth of most bones occurs by endochondral ossification. At the ends of long-bones, cartilage tissue is first added to the growth zones (the growth plates) between epiphyses and metaphyses, and then the cartilaginous scaffold is transformed into bone tissue in the adjacent metaphysis with the help of osteoblasts and osteoclasts (Schoenau et al. 2003, Rauch 2005). Most of the tissue produced by the growth plate will eventually become diaphyseal bone; periosteal resorption occurs at the metaphyses by osteoclastic function (Baron 2003). Vertebral bodies are primarily cartilaginous, and form mainly from growth of the primary and secondary ossification centers (anular or ring epiphyses) on the superior and inferior edge of each typical vertebra. Vertebral bodies are mineralized bone at birth; epiphyses appear in radiographs during puberty around 12 to 15 years (Moore 1988).



Remodeling is the process by which bone is continuously turned over by coordinated actions of resorption and formation. Remodeling allows the maintenance of the shape, quality, and size of the skeleton by repairing microfractures and by modifying the structure (Parfitt 2002). Remodeling occurs in bone multicellular units (BMU) as first described by Frost in the 1960's (Frost 1966), formed by closely working (coupled) osteoclasts followed by the large group of osteoblasts. In normal mature bone, up to 80% of the cancellous bone surface and 95% of the intracortical surface is covered by lining cells. Thus, there is constant matrix remodeling of bone in up to 10% of all bone mass at any point in time; 25% of trabecular bone and 2-5% of cortical bone is replaced annually in adults (Baron 2003). The osteoclasts move in trabecular bone at a speed of approximately 25 µm/day, digging a trench with a depth of 40 to 60 µm. The remodeling cycle lasts about 3 to 4 months, where the phase of resorption is 2 to 3 weeks, reversal phase is 4 to 6 weeks, and the final formation phase, where osteoblasts lay down bone until the gap is completely replaced by new, is up to 4 months (Hadjidakis et al. 2006). During the growth period, about 5% additional bone is formed in every remodeling cycle as compared to resorption (Parfitt et al. 2000). The balance of the remodeling cycle in a young adult skeleton is close to zero, for as much bone is formed as is removed. After the fifth decade of life, bone formation rate fails to keep pace with resorption activity, and bone loss begins.

MECHANICAL LOADS

Hormones and nutrition play a modulating role, but bone development is predominantly controlled by local factors in response to the mechanical stimuli that act on the bone. It was proposed, as early as the 1870's by orthopedic surgeon Julius Wolff, that altered mechanical usage can cause a bone to change its architecture (Wolff 1870). The strength of bones is dependent on the quality and size. While the potential size of bone and muscles are determined mainly by genetic factors, the actual development of muscle and bone during growth is influenced by forces associated with gravity (body mass) and physical activity (Schoenau et al. 2002a). Bone size and mineral density are influenced by physical stimuli (strain); low usage swifts bone to a state of low remodeling, resulting in thinner cortices. Higher strain, up to a certain point, accelerates bone formation and induces bone modeling, leading to thicker trabeculae and cortices. At some point, strain overpasses the bone's ability to adapt, and fracture occurs. The intrinsic control of bone whether new bone is added or taken away from the skeleton is called "mechanostat", a theory described by Frost, and a refinement of the Wolff's law (Frost 1987). The mechanostat theory has been updated with results from new methods assessing bone, and the sensing role of osteocyte is thought to be crucial (Frost 2003, Hughes et al. 2010). Already in 1961, Maresh published data obtained from radiographs of children during their first six years of life, and showed similar periosteal apposition rates in the femur and humerus at age 12 months, but four times faster in the femur at age 33 months (Maresh 1961). Disorders that result in absence or removal of mechanical stimuli during growth, such as cerebral palsy, spina bifida, or poliomyelitis, lead to thin bones in the affected extremities (Gooding et al. 1965, Roh et al. 1973, Ráliš et al. 1976). On the other hand, due to altered mechanical stimuli, rapid periosteal apposition can occur as well. In experimental and patient studies with large bony defects, the neighboring bones strengthen and replace the weight-bearing function of the removed bone.

BONE BIOPSY (IV)

A full-thickness transiliac bone biopsy sample was obtained from 24 children with suspected severe primary osteoporosis in Study IV. A double-labeling course, with 10 day interval period and with per oral tetracycline, was introduced three weeks prior to the procedure. Bone samples were collected 3 or 4 days after the last labeling period.

The biopsies were performed as outpatient procedure in an operating room at the Children's Hospital, all by the same operator (M. Mäyränpää). The procedure required general anesthesia in all but two adolescent patients, on whom only local anesthesia was used. The transiliac biopsy was performed from a standardized location of anterior superior iliac spine as described by Recker (Recker 2008).

Biopsy specimen was drilled manually with a specific bone needle of inner diameter 5 mm (in 6 patients) or 7.5 mm (in 18 patients). The patient was placed in supine position with a small rise under the pelvis and the ipsilateral knee, and with the ilium and umbilicus exposed; the anterior ilium was cleaned draped. The biopsy site, located 2 cm posterior to the anterior-superior iliac spine, was identified; lidocaine was used to anesthetize the skin, subcutaneous tissue, and periosteum of the iliac bone. A vertical skin incision of 2 to 3 cm was then made by scalpel. The underlying muscle and fascia were separated by blunt dissection until the lateral iliac periosteum was exposed; it was then incised and pushed aside. The pointed trochar was inserted through the outer guide sleeve and then inserted through the skin incision, then applied firmly to the exposed bone, pointing toward the umbilicus. The outer guide was rotated until firmly implanted and anchored to the lateral ilium. At this time, the pointed trochar was withdrawn and the trephine inserted through the outer guide. The trephine was rotated clockwise with a steady moderate pressure until the trephine had advanced through the full depth of the ilium. The trephine was then removed, and the blunt extractor inserted through the top of the trephine, gently pushing out the bone core specimen. To control hemostasis, bony defect was packed with absorbable hemostat (Surgicel® Fibrillar, Ethicon, Somerville, NJ, USA), skin incision was closed with sutures in layers, and the site covered by a pressure dressing for 24 hours.

METHODS USED IN THIS THESIS.

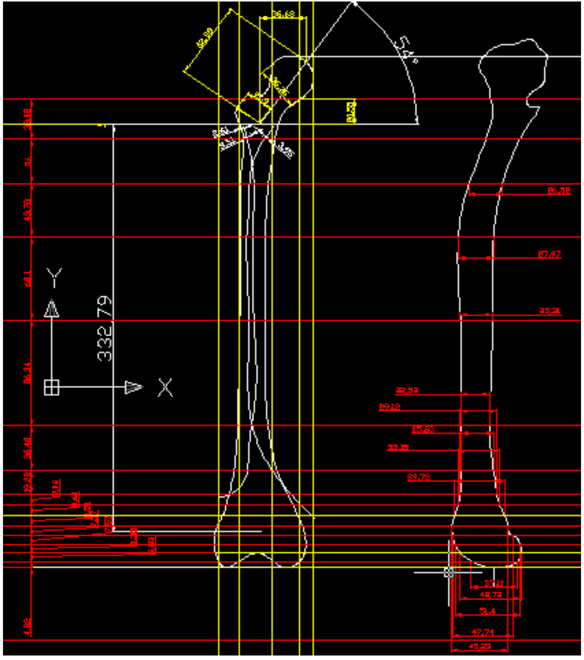
Fracture history
Clinical assessment
Biochemistry
Radiography
Bone densitometry
Vertebral assessment with densitometry
Bone biopsy and histomorphometry

ETHICAL CONSIDERATIONS

The study protocol was approved by the Research Ethics Board of Helsinki University Central Hospital (Dnro. 442/E7/2004). The participants were fully informed about the study, they attended it on a voluntary basis, and the use of the collected information for medical research was explained to them. An informed written consent for participation was obtained from parents, and assent from children for the bone health assessment study (II), in accordance with the Declaration of Helsinki. Bone biopsies (Study IV) and spinal radiographs (Studies III and IV, and partly in Study II) were obtained from children for clinical reasons. Bone biopsy was performed under general anesthesia in all but two adolescent patients, who agreed to the use of local anesthesia with an option for conversion to general anesthesia. The study subjects were informed about the findings of the examinations, and, if needed, further referred for appropriate care.

4.4 STATISTICS

Age-and sex-specific fracture incidences were calculated by dividing the number of patients and fractures during the 12-month study period by the number of inhabitants in the same age group, as reported for January 1, of each year studied. Numbers were obtained from Statistics Finland (www.stat.fi).



CAD MODELING OF BONE

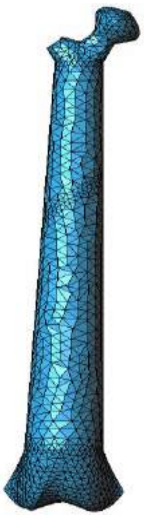
APPLICATIONS

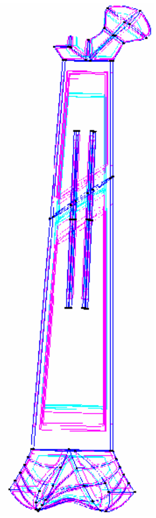
ELEMENT	**CONTENT %**
Aluminum, Al	97.3 - 98.9
Iron, Fe	0.60 – 1
Silicon, Si	0.50 - 0.90
Manganese, Mn	≤ 0.20
Zinc, Zn	≤ 0.10
Copper, Cu	≤ 0.10
Titanium, Ti	≤ 0.080
Chromium, Cr	≤ 0.050
Magnesium, Mg	≤ 0.050
Remainder (each)	≤ 0.050
Remainder (total)	≤ 0.15

Application of FSW includes various industries including few of following: -

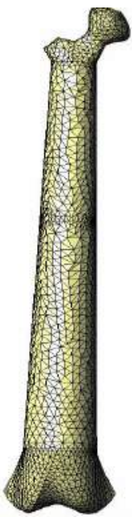
- Shipping and marine industries: - Such as manufacturing of hulls, offshore accommodations.

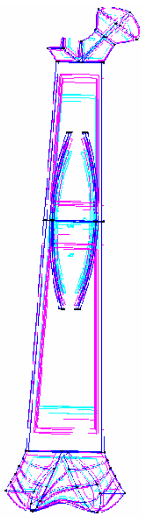
SOLID MODELS





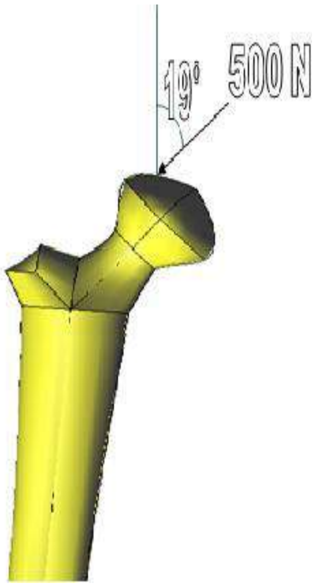
BENDED





UNBENDED

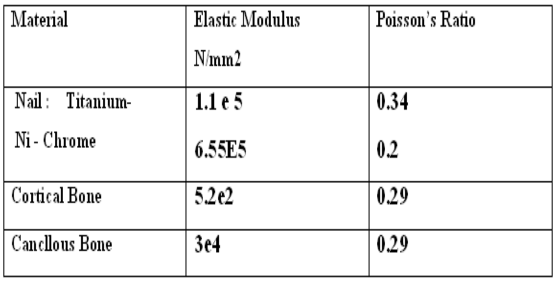
LOADING CONDITION



BOUNDARY CONSTRAINS

	Nodes	**Elements**
Model 1 (Unbended)	5093	24293
Model 2 (Bended)	8165	32000

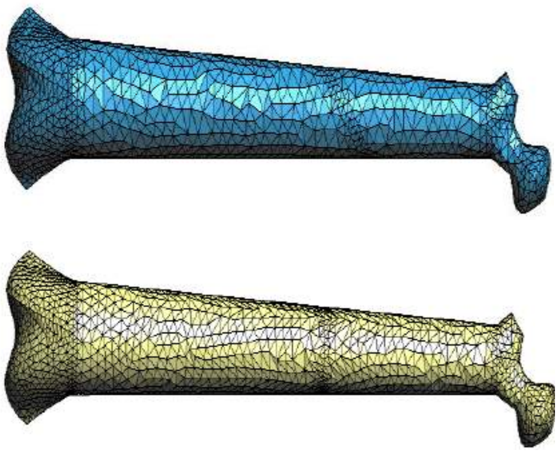
MESH GENERATION

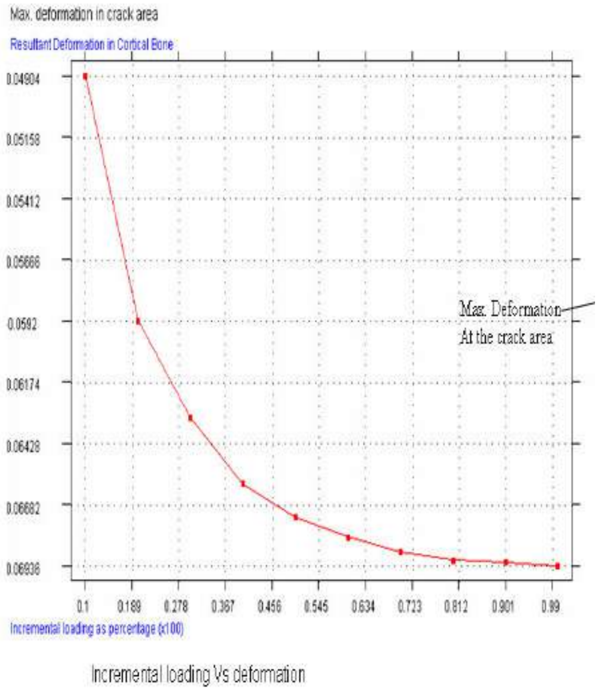


Material	Elastic Modulus N/mm2	Poisson's Ratio
Nail : Titanium- Ni - Chrome	1.1 e 5 6.55E5	0.34 0.2
Cortical Bone	5.2e2	0.29
Canellous Bone	3e4	0.29

MATERIAL PROPERTIES

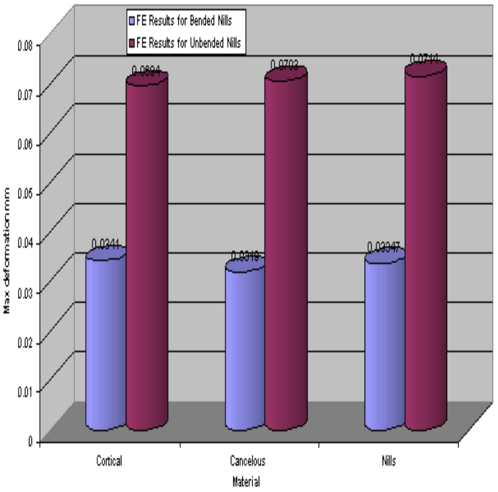
MESHING OF BONE

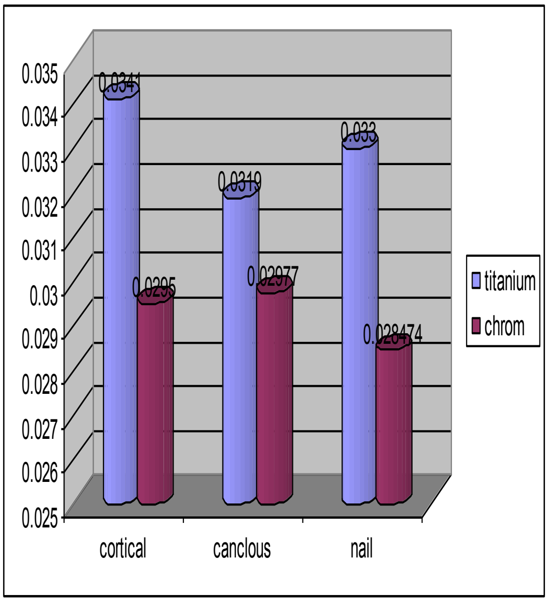




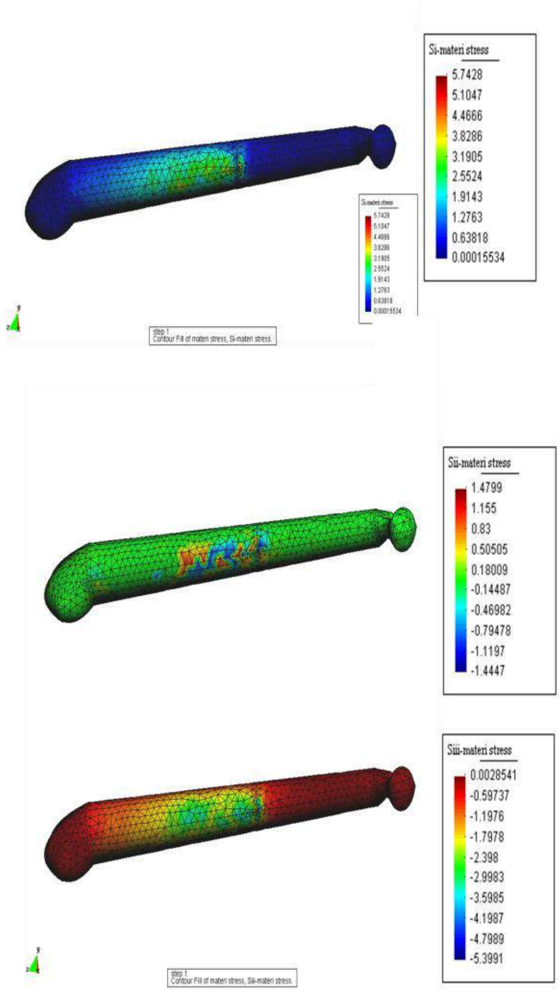
Incremental loading Vs deformation

DEFORMATION RESULTS

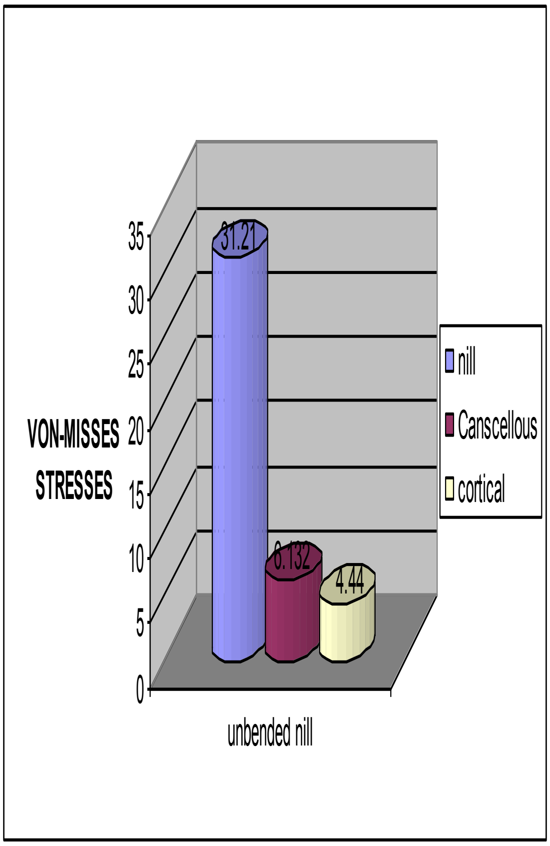




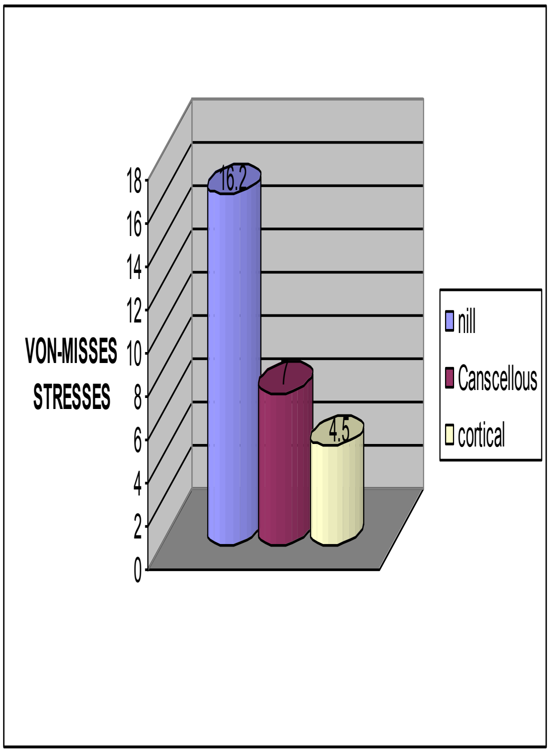
TITANIUM VS NI- CHROM



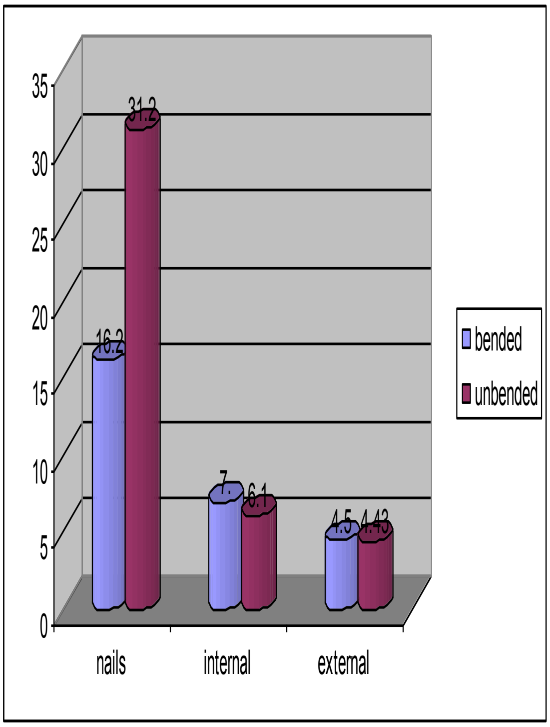
PRINCIPLE STRESS SI ,SII ,SII FOR CORTICAL



VON-MISSES STRESSES (UN BENDED NAILS)

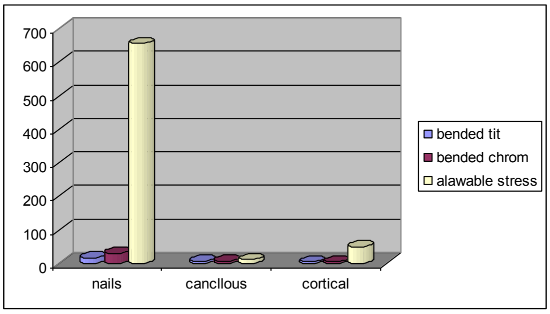


VON-MISSES STRESSES (BENDED NAILS)



BENDED NAILS VS UNBENDED

ALLOWABLE STRESS



	titanium-Von misses	Ni-Chrom -Von misses	allowable stress
nails	16.2	30.166	656
cancllous	7	7.54	11
cortical	4.53	4.433	50

CONCLUSION

Finite element can represent the bone treatment very honestly.The maximum displacement at the crack area was found to be 0.034 mm which is safe and within the practical range.The appropriate material to use is titanium since it is lighter than Ni-chrom and its displacement is almost the same. Thus the employment of Titanium and Nickel Chromium elements in Intramedullary nails is studied.