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Evaluation of mechanical properties of existing material SS316L used as femur bone implant material

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Abstract: *This Research Paper constitutes the study of Mechanical Properties of Tensile, Compression and Bending Strength of the existing material SS316L(readily available) used for orthopedic implant i.e. for Femur prosthesis. According to the ASTM Standards SS316L(readily available) material was purchased of dimension 16mm dia and machining was done according to ASTM standards, the testing for the specimens are conducted by using electronic UTM machine and the mechanical properties of specimens are compared with the Femur bone prosthesis, and hence suggest this Bio-material to use for femur bone prosthesis.*

Keywords – *SS316L, Mechanical Properties, Bio-Material, orthopaedic application-Femur Bone.*

Introduction

The Bone, which is a natural composite material, consists mainly of collagen fibers and an inorganic bone mineral matrix in the form of small crystal called apatite. Collagen is the main fibrous protein, the composite of mineral component in the body. Cartilage is a collagen based tissue which contains large protein saccharit molecules that form a gel in which collagen fibrous are bonded [1]. The Femur is the longest and strongest bone in the skeleton is almost perfectly cylindrical in the greater part of its extent [2]. A Biomaterial is defined as any systemically, pharmacologically inert substance or combination of substances utilized for implantation within or incorporation with a living system to supplement or replace functions of living tissues or organs. The main fundamental requirements that orthopedic devices must fulfil in order to function adequately are summarized as follows.

- Biocompatibility.
- Appropriate Design and Manufacturability of Implants, Mechanical and Biological Stabilities.
- Corrosion Resistance.
- Resistance to Implant Wear and Aseptic Loosening.
- Properties of Biomaterials. [3]

Biomaterial devices used in orthopedics are commonly called *implants*; these are manufactured for a great number of orthopaedic applications [12] *Requirements of Biomaterials [4]* The following are the requirements of a Biomaterial:

- It must be inert or specifically interactive.
- It must be Biocompatible.
- Mechanically and chemically stable.
- Biodegradable.
- Processable (for manufacturability): It must be machinable, moldable, and extrudable. Nonthrombogenic (if blood contracting).
- Sterilizable.
- Non-carcinogenic, non-pyrogenic, non-toxic, non-allergenic, blood compatible, non-inflammatory.
- Physical Characteristics Requirements: Strength, Toughness, Elasticity, Corrosion-resistance, Wear resistance, Long term stability.

Ways in Which Materials Can Fail [5]

1. Corrosion
2. Fatigue
3. Wear

Orthopaedic surgeons have been using metallic bone plates for the fixation of humerus bone fractures. Apparently, metallic prosthesis, which are generally made of stainless steel and titanium alloys, cause some problems like metal incompatibility, corrosion, magnetism effect, anode-cathode reactions, including a decrease in bone mass, increase in bone porosity, and delay in fracture healing [6, 7, 8]. Implants used in medicine for bone osteosynthesis have to satisfy functional demands defined by the working environment of human body. Ideally, they should have biomechanical properties comparable to those of autogenous tissues without any adverse effects.[10] and they found that it is with a confidence to say that metals will continue to be used as biomaterials in the future[11].

EXPERIMENTAL PROCESS

DESCRIPTION: STAINLESS STEEL –

316 / 316L is an 18/8 austenitic stainless steel enhanced with an addition of 2.5% Molybdenum, to provide superior corrosion resistance to type 304 stainless steel. 316/316L has improved pitting corrosion resistance and has excellent resistance to sulphates, phosphates and other salts. 316/316Lhas better resistance than standard 18/8 types to sea water, reducing acids and solution of chlorides, bromides and iodies.[13]

TENSILE PROPERTIES:

As per ASTM E- 08 The test methods cover the tension testing of metallic materials in any form at room temperature, specifically, the methods of determination of yield strength, yield point elongation,

COMPRESSIVE PROPERTIES:

As per ASTM E-09 The specimen is subjected to an increasing axial compressive load; both load and strain may be monitored either continuously or in finite increments, and the mechanical properties in compression determined Compressive properties are of interest in the analyses of structures subject to compressive or bending loads or both and in the analyses of metal working and fabrication processes that involve large compressive deformation such as forging and rolling. For brittle or non ductile metals that fracture in tension at stresses below the yield strength, compression tests offer the possibility of extending the strain range of the stress-strain data. While the compression test is not complicated by necking as is the tension test for certain metallic materials,

BENDING TEST :

As per ASTM E- 290 Static and fatigue flexural properties, such as flexural strength and modulus, are determined by ASTM E-290 test method. In this test, a SS316L specimen of rounded cross-section is loaded in either a three-point or a four-point bending mode. In either mode, a large span (*L*) to thickness *(t)* ratio of 16, 32, 40, or 60 is usually recommended to minimize inter laminar shear deformation.

TESTING METHODS

Fig 1.Universal testing machine

Universal testing machine specification
Capacity: 40ton
Motor: 2.3hp
Voltage: 400 to440 volts
Dimension: L*W*H (2060*750*2180)

Standard Attachments

1. Compression plates 2 no's diameter 120 mm
2. Shear attachments 1 set
3. Extensometer 1 no's
4. Single point bending tool 1 no's

Specification of ASTM standard is **E-08** for Tensile Test Specimen:-

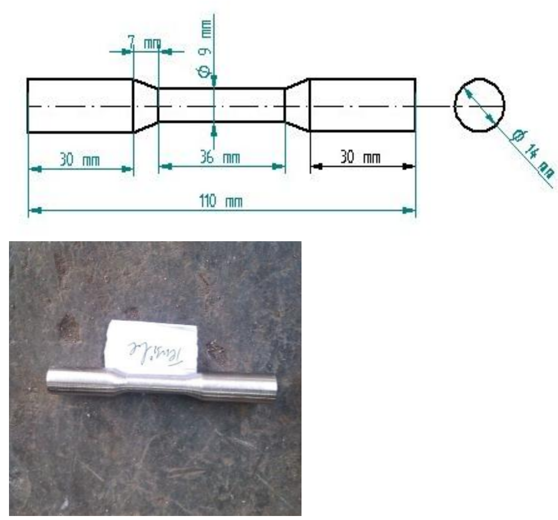

Fig 2.Tensile Test Specimen

RESULTS AND DISCUSSION

Specification of ASTM standard is **E-09** for compression Test Specimen:-

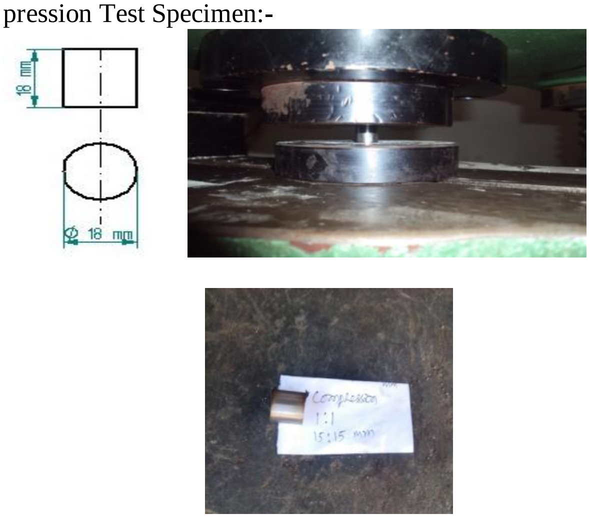

Fig 3.compression Test Specimen

Specification of ASTM standard is E-290 for Bend test Specimen:-

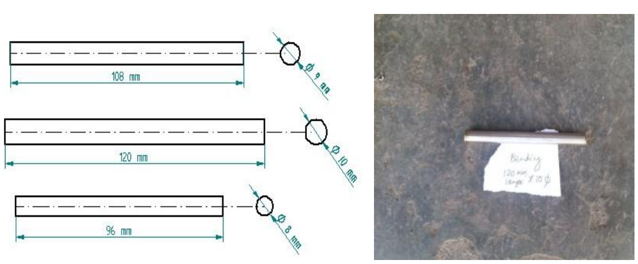

Fig 4.Bend test Specimen

TENSILE RESULTSTENSILE TEST RESULTS FOR SS316L

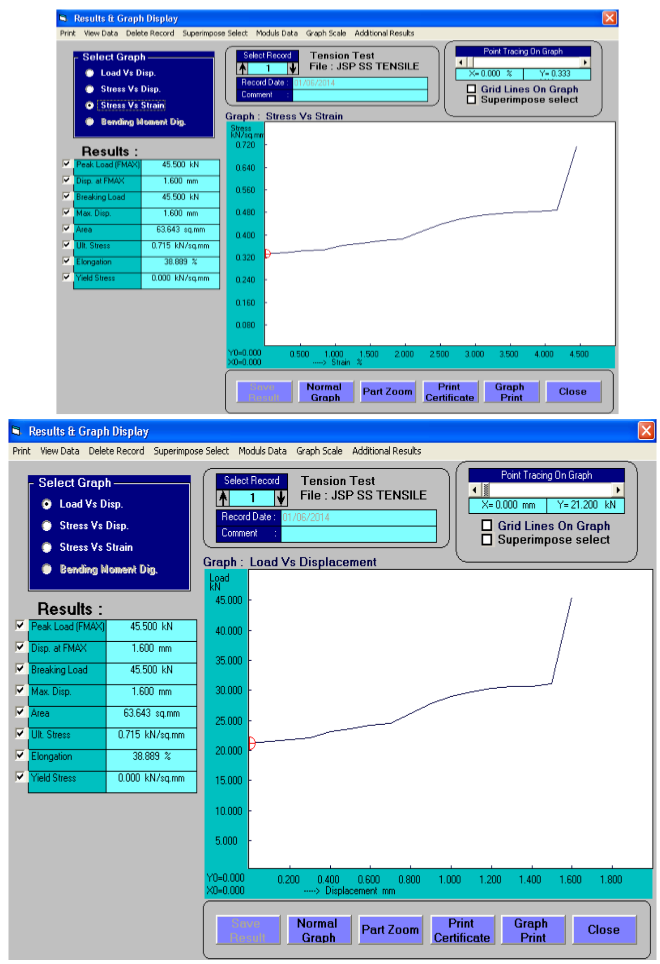

Fig 5.Graph shows *SS316L* for Tensile Test

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Sl No	Peak Load (FMAX) kN	Displacement at Fmax (mm)	Breaking Load (kN)	Maximum Dis-placement (mm)	Area mm²	Com-pressive strength (PKL/ Area) (kN/mm²)	Femur Bone Compressive Strength [12]
1	214.300	2900	214.300	2900	176.86	1.212	115.29±12.94(Mpa) or 0.11529±0.01294 (kN/mm²)

Table 1: Tabular column shows Experimental graph results of Tensile Test. SS316L

Conclusion: From this Experimental Results concluded that the Specimen having Tensile Strength of 0.715kN/mm². Hence comparing this result to the Femur Bone Tensile

sno	Peak Load (Fmax) kN	Displacement at Fmax (mm	Breaking Load (kN	Maximum Displacement (mm)	Area mm²	Ultimate Stress /(kN/mm²)
1	45.500	1.600	45.500	1.600	63.643	0.715
Elongation %		Yield Stress (kN/mm²)		Femur Bone Tensile Strength or Ultimate Stress [12]		
38.899		0.000		0.04344±0.00362 kN/mm²		

Table 2: Tabular column shows Experimental graph results for Compression Test SS316L

Strength0.04344±0.00362 kN/mm², the specimen result will match.

COMPRESSION TEST RESULTS FOR SS316L

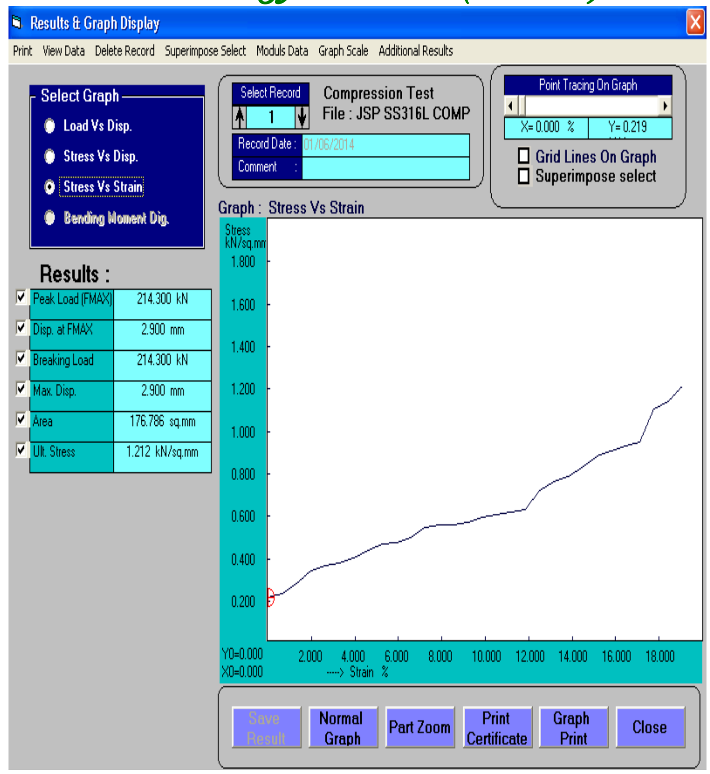

Fig 6.Graph shows Compression Test for *SS316L*

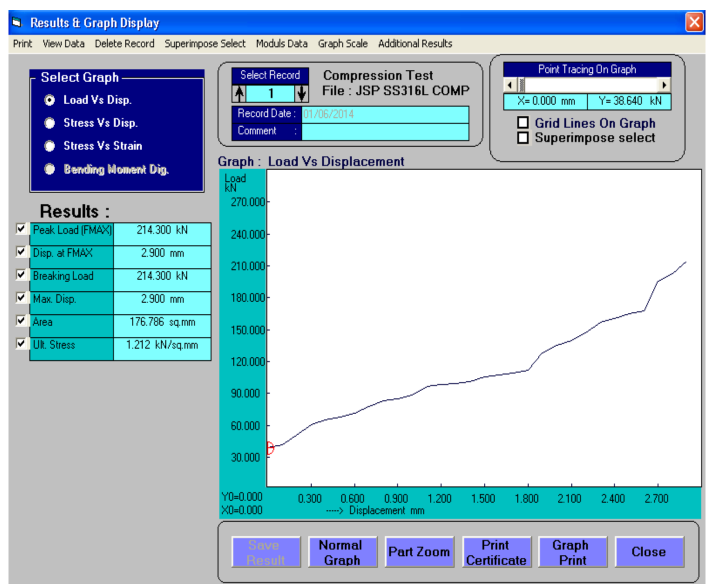

Fig 7.Graph shows Compression Test for *SS316L*

Conclusion**:** From this Experimental Results concluded that the Specimen have Highest Compressive Strength i.e.,1.212 kN/mm² ,Hence comparing this result to the Femur Bone Compressive Strength of 0.11529±0.01294 kN/mm², the specimen results will match.

BENDING TEST RESULTS FOR SS316L

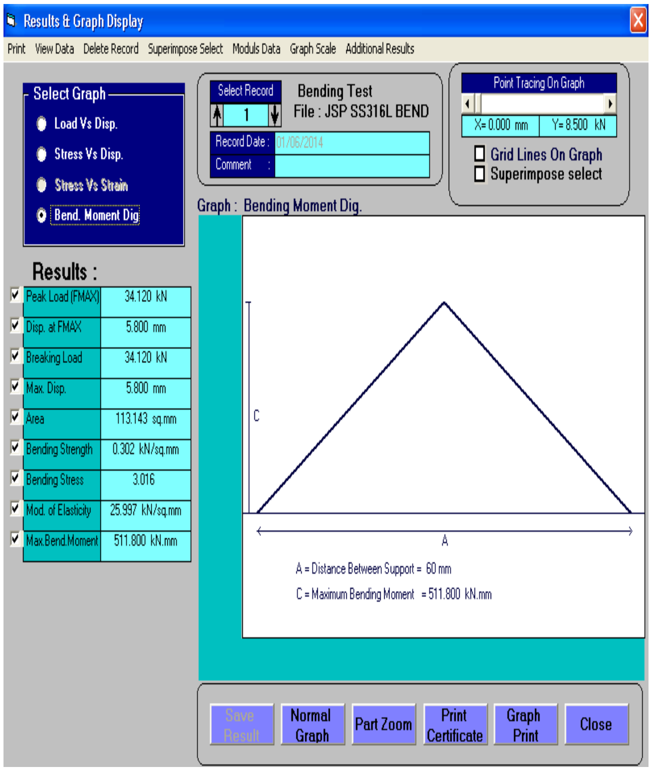

Fig 8.Graph shows Bending Test result for SS316L

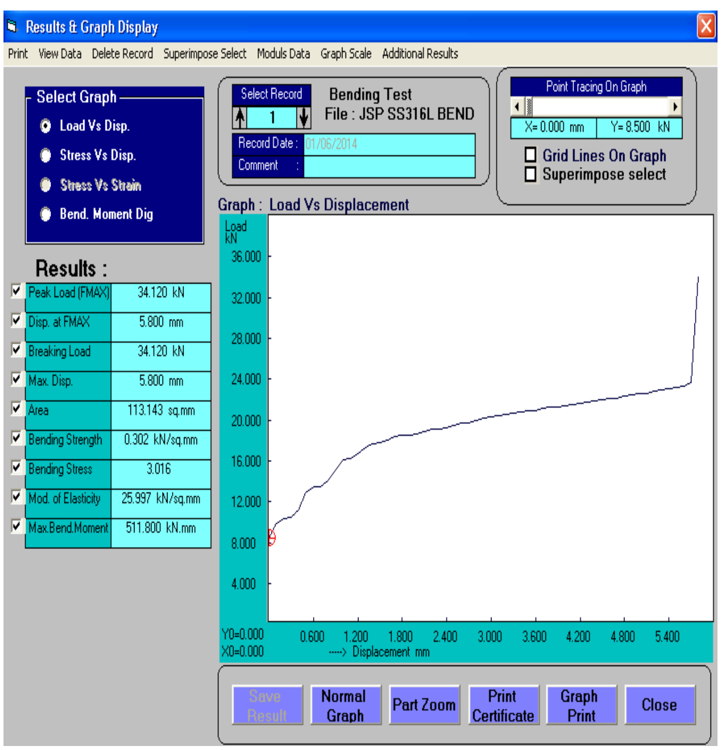

Fig 9.Graph shows Bending Test result for SS316L

Table 1: Tabular column shows Experimental graph results for Bending Test SS316L

Sl No	Peak Load (Fmax) kN	Displacement At Fmax (mm)	Breaking Load (kN)	Maximum Displacement (mm)	C/S Area mm^2
1	34.120	5.800	34.120	5.800	113.143
Bending Strength (kN/mm^2)	Bending Stress (kN/mm^2)	Modulus of Elasticity (kN/mm^2)	Maximum Bending Moment kN.mm	Femur Bone Bending Strength [12]	
0.302	3.016	25.997	511.800	84.03±9.91 (Mpa) or 0.084±0.00991 (kN/mm^2)	

Conclusion: From this Experimental Results concluded that the Specimen have Bending Strength 0.302 kN/mm^2. Hence comparing this result to the Femur Bone Bending Strength of 0.084± 0.00991 kN/mm^2, the specimen results will match.

CONCLUSION

- From the Tensile Experimental test results of SS316L it is found that will match the Femur bone tensile property anyhow from this results we suggest SS316L for femur bone prosthesis.
- From the Compression Experimental test results of SS316L it is found that will match the Femur bone compression property anyhow from this results we suggest SS316L for femur bone prosthesis.
- From the Bending Experimental test results of SS316L it is found that will match the Femur bone bending property anyhow from this results we suggest SS316L for femur bone prosthesis.

FURTHER WORK

- Corrosion Test to be Conducted
- For SS316L material coating will be done by different bio-compatible coating material.
- Finite Element Analysis will be carried out.
- Testing like Fatigue test, shear test, Impact test, Moisture content test and thermal test
- We can compare the existing/ widely using material (SS316L) with Natural fiber (Sisal, Jute, Hemp fibre) or S-Glass fiber or E-Glass fiber or Hybrid Polymer composite material and these properties can be comparing to Orthopaedic Implants especially for Femur Prosthesis.

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