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INTELLIGENT CERVICAL COLLAR - SELECTION AND TESTING OF MATERIALS

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Abstract: *This paper presents a low-cost solution for an intelligent cervical collar by improving an existing cervical collar. It will achieve total immobilization of the cervical spine, using an immobilizer extended system for head and superior thoracic vertebrae. Starting from an existing rigid cervical collar, this was modified in order to increase immobility level. CAD model will be realized using a 3D printer or manufacturing it from plastic materials. Because it is provided with a system for monitoring vital functions, physicians work will be simplified so, after fitting neck brace, they can turn their attention to other priority needs or injuries of the patient.*

Key words: *cervical collar, CAD model, FEA, support.*

1. Introduction

Cervical collars are mainly used in traumatic lesions of the neck or head and the most important application is the spinal cord damage. This device is normally used during an emergency situation for immobilization and prevention subsequent injury. Also cervical collars are used to treat neck pain [1].

Today the most commonly used are collars made of soft foam sponge, polyethylene or rigid materials [2].

There are many models that combine the utility of the core being a combination of their and are provided with adjustable chin support, equipped with tracheostomy window, fitted with Velcro fastening and immobilization system, adjustable height and available sizes [2]. But nowadays doesnĝt exist cervical collars equipped with systems for monitoring vital signs and warning system about patient's condition.

2. Construction of the Cervical Collar

The initial cervical collar was a rigid brace, (Fig.1) universal size, suitable for neck circumference between 310 and 480 (mm) [3]. The back of the neck brace is not rigid enough to provide full support. So, it was necessary to take into account the design of an extension model using SolidWorks software (Fig. 2). By using this extension, the degree of immobilization of the cervical spine will increase to 100% [3]. CAD Model dimensions are higher than the original ones [only 175 (mm) length], plus that will provide stability. Because his up limit is on top of the head and lower limit to thoracic vertebrae T3-T4, with this improvement it will block the entire head and neck complex [2].

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Fig. 1. *Cervical collar Philadelphia Ortel C4 Vario Model [3].*

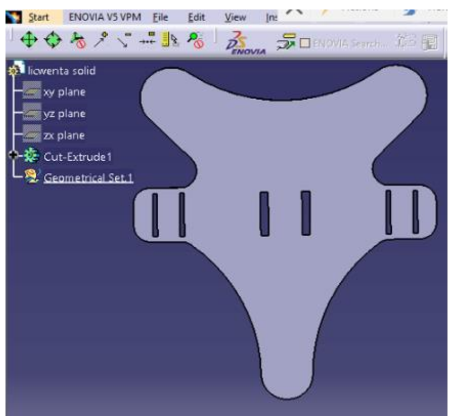

Fig. 2. *CAD model of the extension [2]*

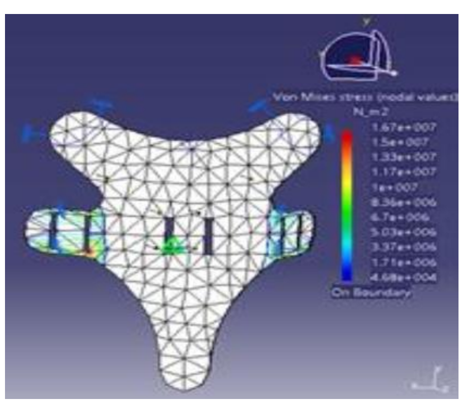

Fig. 3. *FEA analysis of the extension*

CAD model realized in Solid Works, was imported in CATIA V5. So, using Finite Element Analysis (FEA), its resistance to various forces can be tested or to check if an assembly is or not removable (Fig.3). After achieving FEA analysis for different plastic materials, were realized various prototypes, to be subjected to real stress like torsion, tensile, shear or bending. Prototypes were made of plastic materials like polyethylene (PE), polyvinyl chloride (PVC), polystyrene and polylactic acid [4].

The polyethylene (PE) is a thermoplastic polymer resulting from ethylene monomer polymerization. It has a high resistance to impact, modest structural strength and good resistance to chemical attack.

The Polyvinyl Chloride (PVC) is obtained from vinyl chloride monomer polymerization. It is thermoplastic and it has an amorphous structure [4].

Guttagliss is PVC, used in different domains, with good resistance to weather, good thermal properties and smooth, nonporous surfaces. The polystyrene is obtained by mass polymerization, emulsion or solution of styrene. Acrylonitrile butadiene styrene (ABS) is the most used polystyrene. It has high resistance to impact or contact with different abrasive bodies and also high resistance to alkaline or acid solutions.

3. Materials testing

In order to achieve cervical collar support different plastic materials of different thicknesses and compositions were purchased. For materials mechanical testing, a series of specimen were realized with the dimensions shown in the Figure 4.

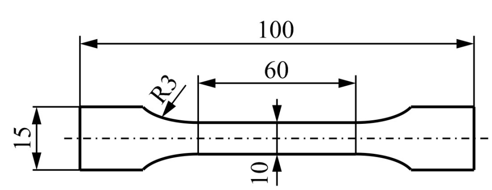

Fig. 4. *Specimen dimensions*

Six types of plastics with different thicknesses and chemical composition were purchased. These were processed into test specimens, in accordance with the dimensions shown in the Figure 5.

As the exact composition of the purchased plastics was unknown, they were labelled M1, M2, M3, M4, M5 and M6. For each type of material, two specimens were manufactured to minimize potential errors.

M1 ... M6 are graded materials of different thicknesses ranging from the thinnest of 0.6 mm to the thickest of 3.7 mm.

Fig. 5. *Test specimens made of the plastic materials*

Fig. 6. *Testing Machine Lloyd LS 100 plus*

To determine the elastic modulus and tensile strength, specimens were loaded using a testing machine Lloid LS 100 Plus (Fig.6). Plus LS 100 is a modern mechanical testing machine, which offers a number of possibilities in terms of how load but registration and results processing.

Results obtained in mechanical testing of plastic materials

Table 1

Sample	Thickness *mm*	Area mm^2	Stiffness *N/m*	Young's Modulus *MPa*	Maximum Load *kN*	Stress at Maximum Load *MPa*	Extension at Maximum Load *mm*	Strain at Maximum Load
M1	3.7	37	1018677	1376.59	0.758	20.505	1.348	0.026
M1	3.7	37	985399	1331.62	0.732	19.795	1.195	0.023
M2	1.7	17	791781.7	2328.77	0.283	16.679	0.406	0.008
M2	1.7	17	744364	2189.306	0.282	16.603	0.460	0.009
M3	2.9	29	5341.072	9.208	0.015	0.525	1.998	0.039
M3	2.9	29	5342.034	9.210	0.011	0.394	1.990	0.039
M4	2	20	719101.3	1797.753	0.218	10.909	1.123	0.022
M4	2	20	786896.6	1967.242	0.298	14.940	0.423	0.008
M5	0.6	6	371306.8	3094.223	0.373	62.278	1.280	0.025
M5	0.6	6	390589	3254.908	0.375	62.539	1.486	0.029
M6	1.4	14	683320.4	2440.43	0.728	52.038	1.591	0.031
M6	1.4	14	682259.7	2436.642	0.766	54.784	1.647	0.032

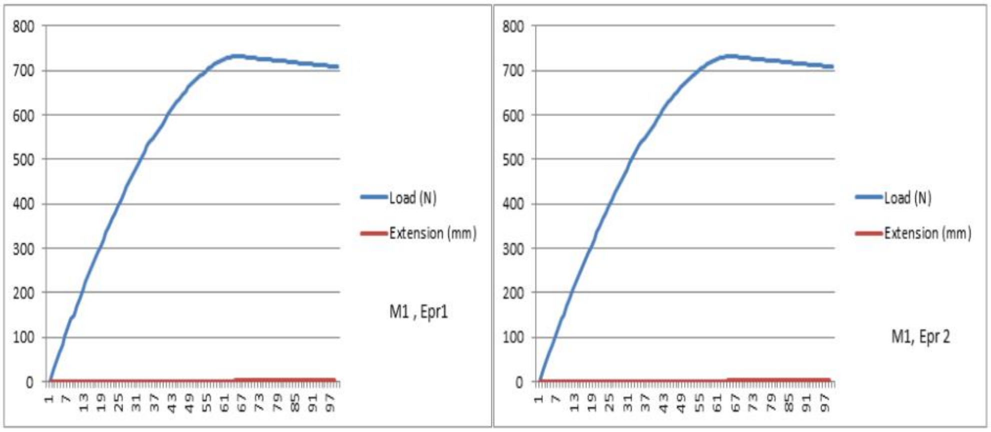

Fig. 7. *Load-Extension Curve for M1 material*

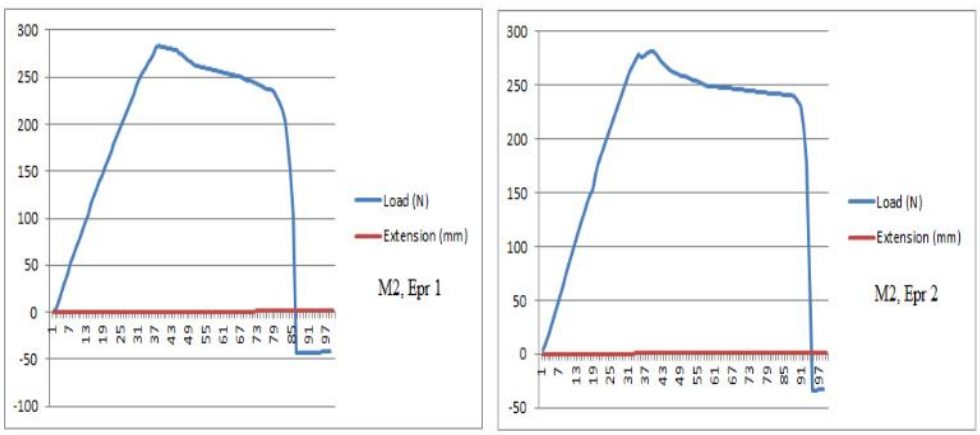

Fig. 8. *Load-Extension Curve for M2 material*

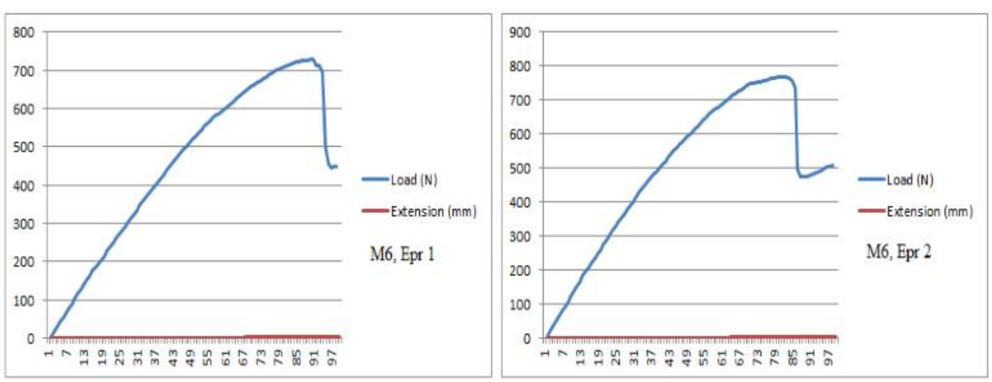

Fig. 9. *Load-Extension Curve for M2 material*

Each plastic material was subjected to tensile following the steps below:

- The samples were numbered and measured, considering two specimens of each material;
- The samples were sequentially fixed on the test bench from material M1 till M6;
- After fixing the specimen, it was applied on a device (Epsilon Technology Corp) for measuring its deformations.

Lack of space, only some of the results of the testing of plastics (for 6 specimens) are presented in Table 1. Load-Extension curves for some specimens are presented in figures above.

Following the completion of testing, the specimens have been changed as can be seen in the figure below M2 and M4 material specimens have failed, the M3 and M5 materials have undergone slight changes gripping surface. The materials M1 and M6 are plastics that remain least affected, which is why they chose FEA subjecting them to analysis in order to obtain optimal structural solution.

Fig.10. *Cut cervical support*

Fig.11. *The final version of the active orthosis*

As presented in Figure 7, the material M1 has a high resistance, withstanding a force 700 N, specimens no cracking, while having a high modulus. Due to favorable results, material M1 was chosen for FEA testing as to eliminate possible errors.

M2 material not recorded favorable results, both specimens giving a thrust of 300 N. Because no results were decided in achieving non-use of material M2 orthosis.

M6 material testing reveals remarkable properties of elasticity and strength. He resisted a request of nearly 800 N, which is why the material was took into account to fabric the orthosis (Figure 10). The final version of active prosthesis is presented in Figure 11.

Cervical support was made of plastic M6 and M1 after successfully coped with analysis and stresses to which it has undergone. It was cut made in accordance with the dimensions of CAD model. Cutting was performed using a jig saw with blade 1.5 mm. After executing the outline, cutouts were made on its joints, it experienced a type Velcro tape, which is to link with the front of the orthosis. (Figure 10). As the material of the support was carried out cervical thermoformable, it was subjected to a temperature of 70°C in order to model its curved for better elasticity and to successfully mold the anatomic segment of interest. After cooling it and kept curved shape.

Conclusions,

Intelligent cervical collar offers a high degree of innovativeness, because, besides the function of restraining overall the cervical spine, it is provided with a comprehensive patient monitoring and display of digital information taken from the body on a TFT screen, attached to the collar.

This collar is equipped with a screen that will display pulse, patient temperature, blood oxygen level and degree of humidity.

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