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STIFFENING PLATES FOR CERVICAL COLUMN

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Abstract: *Cervical column diseases are among the modern society most spread illness especially due to the bad work positions imposed by the new technological procedures. In the aim to reduce patients' pain, a lot of technical solutions already exist as orthoses or other different supporting systems. The paper presents a few examples of posterior cervical plates from literature. In the last part two models designed and fabricated in the Laboratory of Medical Engineering are presented. The devices were subjected to a FEA analysis to observe the behaviour of the material at peak loads that occur in the cervical area, the obtained result being very satisfactory.*

Key words: *spine, cervical vertebrae, plates.*

1. Introduction

The most important part of the bipedal human support is the spine consisting of discrete bony elements called vertebrae that are joined by articulations and ligaments, being maintained at physiological distance by intervertebral discs [1]. It movement is dynamically controlled by muscular activation. Each of the five column regions: cervical, thoracic, lumbar spine, the sacrum, and the coccyx has its own unique set of kinematic functions, pathologies, and treatments [2].

Many causes ï accidental or pathologic can produce the different pathologies of vertebrae or the deployment of intervertebral discs, and/or the degeneracy of both vertebrae and intervertebral discs.

Persons affected by such diseases, may have certain symptoms, and where appropriate, they may be: loss of different intern organs control and acute pains depending on the disease nature and localization [3].

How long brain can communicate with the organs we can talk of health. But if this communication is disrupt by a brain dysfunction or by a critical alignment of vertebrae, pressure points can occur and these may influence the good organs functioning. A study done at Colorado university shows that a very low pressure on a spinal nerve (of about 10 mm Hg column), equivalent to the lightest felt touch of a finger on the eyelid, would reduce the number of nervous impulses and its electrical activity with about 60 % [7].

2. Existing cervical instrumentation

Instrumentation used in interventions on the cervical spine has evolved alike for both types of approaches, posterior and anterior of the basic method to strengthen inter-spinous processes with wires. Posterior stabilization techniques of the

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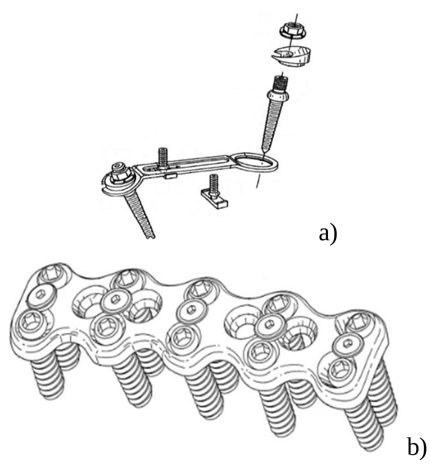
atlanto-axial complex historically used various wiring techniques.

In 1939, Gallie described a relatively simple technique for controlling situations with anterior instability of the atlanto-axial complex. The only requirement for this technique is that integrity of the C2 arch is maintained [4]. Using wires in posterior cervical column was first described by Rogers in 1942 to treat fractures and dislocations of the cervical spine. In 1959 Forsyth described the posterior internal cervical spine fixation technique using 20 stainless steel wires to splice spinous processes [5].

In 1980 Dr. Roy-Camille was pioneer in posterior cervical stabilization using lateral mass screws to the vertebrae (Fig. 1, a). His technique of stabilizing the fusion induced spontaneous deck facets and therefore required no additional grafting [5].



a) b)

Fig. 1. *The system of Dr. Roy-Camille* (a); *AME Haid Universal Bone Plate System* (b).

In 1989 Dr. Haid has developed a posterior cervical plate (AME Haid Universal Bone Plate System) made of titanium alloy to reduce artefacts in CT scans. It had a slightly concave cross-section to accommodate anatomical shapes of the articular processes (Fig. 1, b). The lateral mass plate fixation is independent of the integrity of the posterior elements Fusion success rate was 98% [5].

Using anterior cervical plates provided by fusion stabilization capacity increase selective cervical segments, eliminating the need for external immobilization. A large number of anterior cervical plates have been developed and used clinically for over the years.

In 2002, Haid proposed a nomenclature describing and labelling anterior cervical plates (ACPs) based on biomechanical properties and load capacity of these systems graft. In order to reduce the normal stress against graft, but also preventing unscrewing, semi-constrained plates were created [5]. The objective was to develop a plate that takes only a percentage of the load and distribute evenly across graft the load difference. A system that was built for this purpose was DOC Rod (DePuy Spine, Rayham, MA). It allows translations vertical sliding bolt controlled by the over bars, which leads to compaction graft (Fig. 2, a) [5]. Another example is the Aesculapius ABC plate dynamic system, and presents slots and variable angle screws to reduce positioning of stress shielding, allowing translation and rotation of the screws in the interface.

a) b)

Fig. 2. *DOC Rod System* (a); *Solstice NEO-SL Plate* (b). [5]

NEO-SL System of anterior cervical plate is slim and easy to use, having an integrated locking mechanism that allows bone screws to be securely fixed without the need for additional locking components. Its key features include plates of different lengths for procedures from level 1 to level 5.

3. New solutions for cervical support

In the aim to obtain a better quality-price ratio, two virtual prototypes of posterior cervical plates were designed using CATIA V5R19 and Solidworks2015 software.

3.1. The PCP-01-M prototype

The first prototype PCP-01-M was inspired from DOC Rod system and it allows vertical translations controlled by the over bars, which leads to compaction of the graft (Fig. 3).

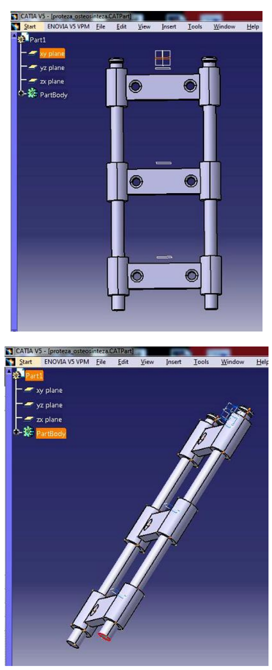


Fig. 3. Design of *cervical plate* PCP-01-M.

The first prosthetic plate prototype was obtained through several stages of processing technology as:

1. Cutting a rod of 150 mm length and 10 mm diameter, in rods of 18 mm length; and cutting a 130x50 mm metal plate in size 34x12 mm pads. Cutting abrasion is very productive, accessible, does not require complex equipment, and it is mainly used in cutting pipes bars and small size. The process applies to slicing networks in casting, especially for ally nonferrous metals.
2. Turning an 18 mm long rod and 10 mm diameter in order to obtain a cylinder with an internal diameter of 6.2 mm.
3. Padôs drilling with a cylindrical shaft drill:
4. Welding together the obtained plates and plugs.
5. Small adjustments by grinding bushes to give the designed shape and size of execution.

Details on materials and their mechanical properties are detailed in [5].

3.2. The PCP-02-F prototype

The second system (PCP-02-F) is simplest and inspired from Solstice NEO-SL as shown in figure 4. Even it is simplest as the PCP-01-M, it presents the advantage to discharge only partially the stress in the vertebrae while the residual stress creates the necessary load to stimulate the bone growth and functioning.

The second prototype was fabricated by two technological procedures: classical and nonconventional technologies, as to have the possibility to compare the two solutions.

The first alternative of the prototype (Fig. 4, b) fabrication included very common classical technologies: cutting, milling, and drilling.

The conventional methods have proven to be time consuming, difficult and, especially, expensive to produce isolated prototypes.

For the second alternative of the prototype (Fig. 4, a) the water cutting procedure was chosen.

a) b)

Fig. 4. *The cervical plates* PCP-01-F obtained by: water jet cutting (a), and classical fabrication (b).

At the very tight competition with laser machining process, is those with water jet, one of the latest cutting processes. Water jet cutting is a technology of multiple edges cutting for which machining is performed by pure water high-speed jets for soft materials or high-speed jet of water mixed with abrasive additives, i.e. hydro-abrasive jet when materials are tough.

This process is based on the following principle of operation: a high-pressure abrasive additive (typically granite) in a mixture of small diameter water jet is controlled oriented on the surface of the processed material. The mixed jet strikes the material with supersonic speed, bombarding him, and detaches small particles of its surface. Cutting technology is based on hydro-jet power of erosion.

As a result of the material removal technology of by abrasive fluid jet, the temperature rise along the cut surface is minimal and, the structure of the material does not change.

The surface quality after cutting can be very rough or very fine, as appropriate, depending on the thickness of the cut piece, the material quality, the water flow applied pressure, the nozzle of the cutter diameter, the diameter and length of the focus/mixture tube, and abrasive grains size and, the cutting speed. By reducing cutting speed and by increasing the amount of abrasive in the composition, the surface roughness can be greatly refined, thus the obtained characteristics can be comparable to those of surface cut by laser.

The equipment for water jet processing (fig. 5) used embedded, in a compact configuration, the high-pressure pump, the cutting system command and control (CNC), the power supply unit, the nozzle for cutting, the tube focus/mixture, the unit supplying with abrasive and, sound absorption equipment.

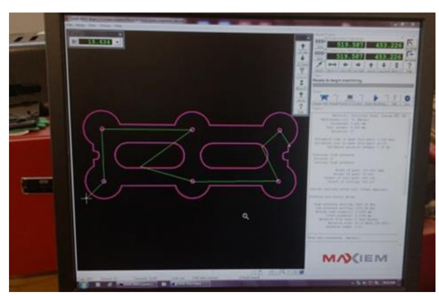


Fig. 5, 6. *Cutting Water Jet Machine (*ICDT*, Laboratory –L3).*

The high pressure pumps can achieve a maximum pressure of 6000 bar. High pressure water jet nozzle is directed by a flexible metal pipe with a diameter of 5-8 mm and 1-2 mm thickness. Through a very small notching of the focus nozzle an extremely high feed rate of water jet is obtained. Workpiece surface during the impact with the cutting water jet can reach a speed of 3600 km/h

In general, the work table is the numerically controlled to meet specific requirements hydro-abrasive cutting. The work area is divided into different segments removable grilles.

Using CNC console, certain work phases can be also programmed on the machine. Depending on the quality and thickness of the material, using cutting software efficient cutting parameters and the required optimal time can be determined.

Data on the overall dimensions, aspects of strength of materials, and fabrication details can be found in reference [5].

3.3. FEM analyse of prototypes

Considering the literature data concerning the loads on cervical zone of the vertebral column [6], for an average subject in static state, both types of models were analysed by FEM. For each or them the elastic-plastic material properties were considered. For the two models PCP-01-F, the geometric connection conditions were kept constant (as they have the same geometric configuration and the same fixing system) but two different materials were considered.

For all FEM modelling and - all models and materials, the results in static state of stress and strain fitted inside the maximal limits of stresses for compression, bending and pressure.

4. Comparison of the technologies used to obtain the two prototypes

In comparing the cervical plates, two principal conditions were defined: the technologic condition and the economic one.

Technologic condition refers to the process designed to achieve a specific product, to ensure compliance with all its technical and quality requirements in terms of a material base determined.

Economic condition assumes that the product is made by applying a technological process, which ensures a minimum cost of production.

The special advantages of water jet cutting opposed to the traditional fabrication are:

- possibility of cutting the three-dimensional shapes;
- no heat affect the processed zones and, therefore, it is to note the absence of thermal hardening and stress;
- possibility of cutting a wide variety of metallic and non-metallic materials;
- facility in integration in an automatic system;
- no further fabrication for good quality cutting surfaces.

Water jet cutting has also disadvantages opposed to the traditional fabrication:

- high cost for processing;
- expensive equipment.

5. Conclusion

The paper presents the design and manufacturing of three prosthetics for cervical column support by conventional (cutting, milling, drilling) and nonconventional technology (cutting with water and abrasive particles jet).

The main conclusion was that the water jet cutting machines replace other four conventional machines in a very short time and with very good qualitative results.

Why the water jet cutting machines? Because they can produce parts of great complexity with a better quality, in a short time.

By reducing the cutting speed and

increasing the abrasive particles quantity in jet composition, the obtained surface ruggedness can arrive at a level comparable with this obtained by laser cutting.

Also, in comparison with water jet cutting, the procedure with composed jet of water and abrasive particles can process a very large range of materials with different thickness and stiffness.

During the manufacturing, the parts are not overheat and deformed under the very high pressure of water.

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