Contact Pressure Measurement in Trunk Orthoses

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***Abstract* — Measurement processes in prosthetic and orthotic practice play critical role in the efficiency of treatment. Pressure is one of the most important parameters that indicates the condition and tendency of the technological process, testing and wearing of the new prosthetic and orthotic aid.**

The pressure distribution between the human body and trunk orthosis was analyzed using thin pressure indicating film. The main goal of the research was to design new pressure measurement methods for optimization of the treatment from the ergonomic, correction and efficiency point of view.

I. INTRODUCTION

Adolescent idiopathic scoliosis (AIS) affects 1–3% of children in the at-risk population of those aged 10–16 years. The aetiopathogensis of this disorder remains unknown (idiopathic), with misinformation about its natural history.

Non-surgical treatments are aimed to reduce the number of operations by preventing curve progression. Although bracing and physiotherapy are common treatments in much of the world, their effectiveness has never been rigorously assessed. [3]

Stefano Negrini and colleagues (2009) carried out the third study published with respect to SRS criteria, and it is the first one that has also fulfilled the SOSORT criteria for bracing studies. The former criteria provide the methodological framework while the latter give the approach together with the technical aspects of the treatment. [11]

Van den Hout (2002) performed pressure measurements which are applicable and of value for the research on the working mechanism of brace treatment. Therefore, they performed pressure measurements on new THORACO LUMBO SACRAL ORTHOSES (TLSO) with a more or less dynamic thoracic brace pad. [5]

Delphine Périé (2003) analyzed Boston brace biomechanics; pressure measurements and finite element simulations were done on 12 adolescent idiopathic clinical framework so as to gather the best possible data on this kind of treatment. The number of patients is low, but the population is comprehensively selected and cohesive.

Results: Median reported compliance during the 4.2±1.4 treatment years was 90%(range 5-106%). No patient progressed beyond 45°, nor was any patient fused, and this remained true at the two-year follow-up for the 85% that reached it. Only two patients (4%) worsened, both with single thoracic curve, 25-30° Cobb and Risser 0 at the start.

They found statistically significant reductions of the scoliosis curvatures (-7.1°): thoracic (-7.3°), thoracolumbar (-8.4°) and lumbar (-7.8°), but not double major. Statistically significant improvements have also been found for aesthetics and ATR. Conclusion: According to our results, in patients at risk it is possible to avoid surgery, provided the patients follow their prescriptions and adhere to the regime of treatment. By respecting the SOSORT criteria and focusing on compliance, a complete conservative treatment based on bracing and exercises will produce much better results according to the SRS criteria than have been reported previously. These results should be verified in the future with a prospective paper that will also include drop-outs, which are failures of treatment. This paper demonstrates the importance of the human

scoliosis patients. The results showed that high thoracic pads reduced both thoracic and lumbar scoliotic curves more effectively than lumbar pads only. The study suggests that mechanisms other than brace pads produce correction and contribute to the force equilibrium within the brace. Technological advances have much improved the ability of surgeons to safely correct the deformity while maintaining sagittal and coronal balance. [6]

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Much has yet to be learned about the general health, quality of life, and self-image of both treated and untreated patients with AIS.

The pressure range in orthotic treatment in adolescent idiopathic scoliosis was analyzed to manage or even reduce spinal curvatures while waiting for skeletal maturation. By applying specific pressure points on the torso, the brace treatment attempts to modify mechanically the scoliotic spine shape and control progression of the spinal curvatures. [4]

Many clinical studies used standard radiographs to assess the brace effectiveness.
To analyze spinal brace biomechanics, pressure measurements in orthosis testing were carried out in four adolescent idiopathic scoliosis patients.

II. MATERIALS AND METHODS

There are few biomechanical contact pressure studies of spinal brace effectiveness and proper function. Biomechanical pressure action is not completely understood. For our research we used pressure sensor films PRESSUREX. (Figure 1.)

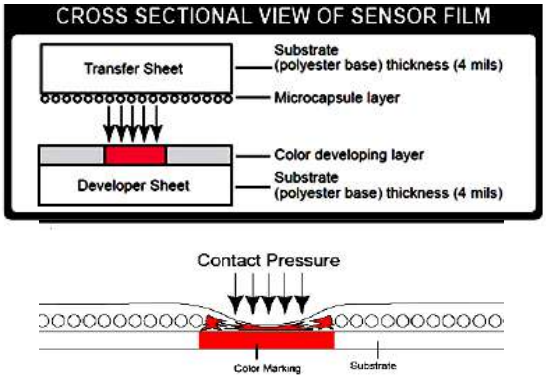


Figure 1. : pressure sensor films PRESSUREX

Pressurex is an affordable and easy to use tool that reveals the distribution and magnitude of pressure between any two contacting, mating or impacting surfaces. Pressure indicating sensor film is thin (0,1016 to 0,2032 mm) which enables it to conform to curved surfaces. It is ideal for invasive intolerant environments and tight spaces not accessible to conventional electronic transducers. [2]

Pressurex is a mylar based film that contains a layer of tiny microcapsules. The application of force upon the film causes the microcapsules to rupture, producing an instantaneous and permanent high-resolution "topographical" image of pressure variation across the contact area. [2]

TABLE I.
TYPES OF PRESSURE SENSITIVE FILMS

Type	Pressure RANGE
MICRO	0,14 – 1,4 kg/ cm2
ZERO	0,5 – 2 kg/ cm2
ULTRA LOW (A)	**2 – 6 kg/ cm2**
SUPER LOW (B)	**5 – 25 kg/ cm2**
LOW (C)	**25 – 100 kg/ cm2**
MEDIUM	100 – 500 kg/ cm2
HIGH	500 – 1300 kg/ cm2
SUPER HIGH	1300 - 3000 kg/ cm2

Pressure film is used to be placed between any two surfaces that touch, mate or impact. The procedure of pressure film application includes: applying the pressure, removing it and the film reveals the pressure distribution profile that occurred between the two surfaces. Like Litmus paper, the color intensity of the film is directly related to the amount of pressure applied to it. The greater the pressure, the more intense the color. (Table I.)

It can measure surface pressure distribution whether it is used as an impact force sensor, seat pressure sensor, as a strain gauge or even as nip impression paper.

Pressurex has a wide array of applications. Our pressure indicating film acts as a force-sensing resistor between the patient's skin and orthoses (Figure 2.) [2].

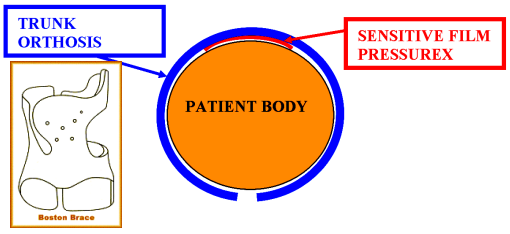


Figure 2. : scheme of measurement system between body and trunk orthosis.

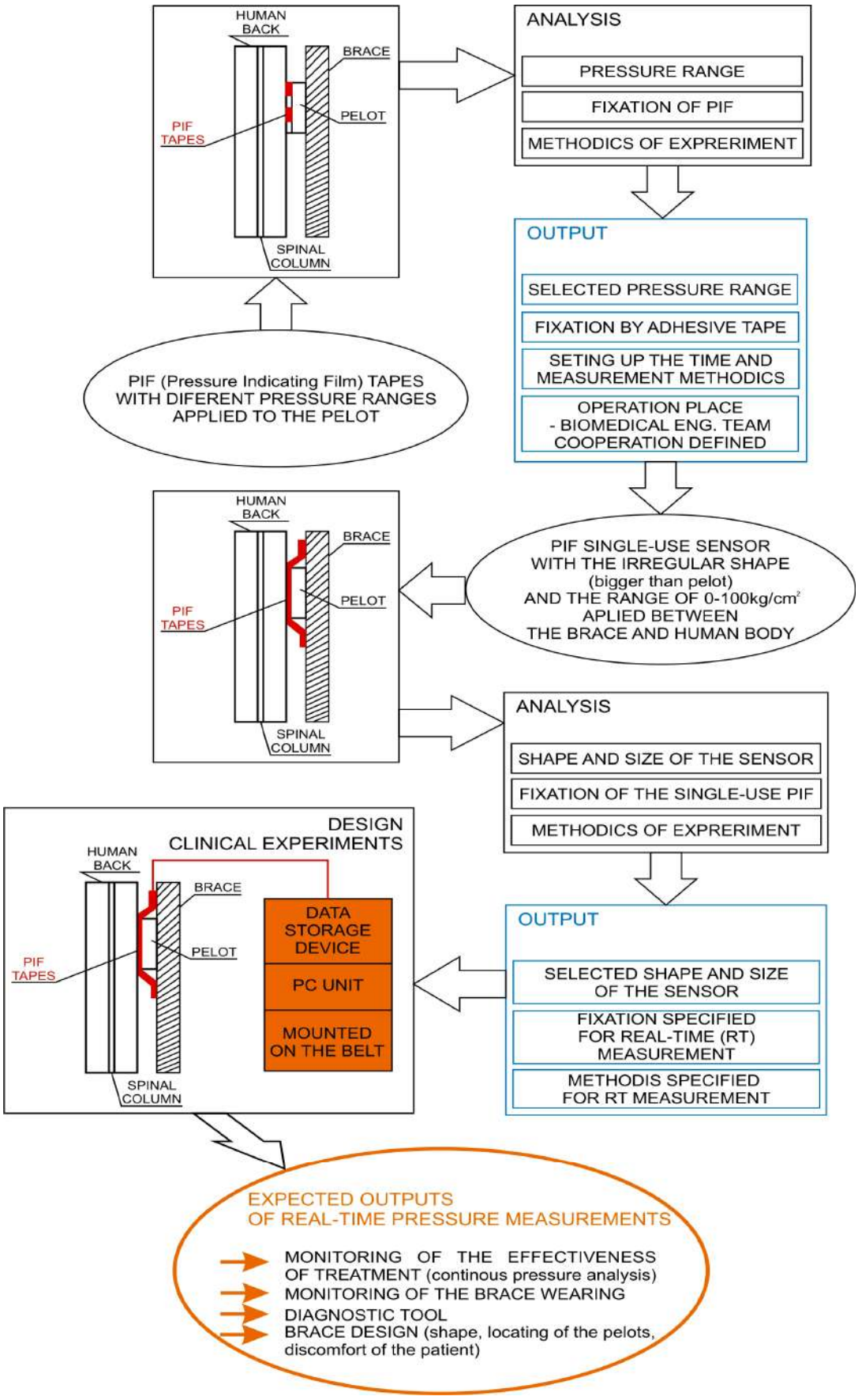


Figure 3 : The scheme of optimalization the application pressure indicating films application between the human body and brace.

III. RESULTS

An initial study was performed in 3 female and 1 male patients (children) with scoliosis treated with the spinal orthoses brace system. An experimental protocol was composed by the acquisition of two sets of pressurex films (Figure 3).

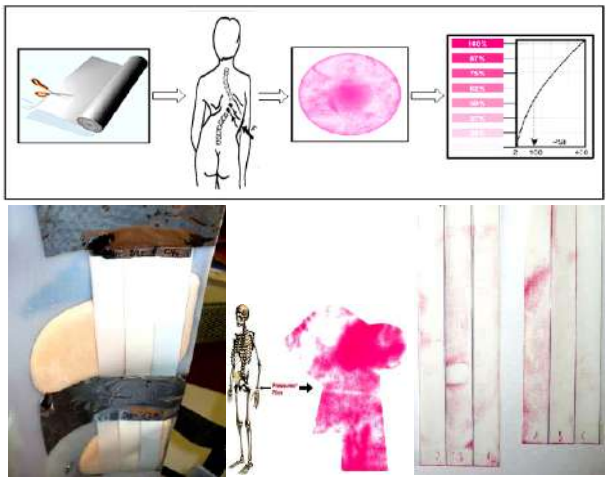


Figure 4. : PRESSUREX sensor films during measurement process.

The Topaq software system is designed to be used in conjunction with pressure indicating films (Figure 5). Utilizing a specially adapted flatbed scanner, scans and interprets these films and determines the exact pressure applied at every point across the film surface at resolutions up to 1000 DPI. The maximum film dimension that can be scanned at one time is 12" x 17".

Software has many analysis tools that give flexibility in scanning entire images or just small areas of an image. Statistics can be generated on the local regions or the entire scanned area. Software displays the image in 3 distinct formats: as the actual scanned image looks, as a pseudo color representation of the scanned image with different colors corresponding to different ranges of pressure, and as a three-dimensional image. Additionally, software allows you to plot a histogram and log all the data collected for conversion into formats accepted by other popular spreadsheet programs for further analysis. [2]

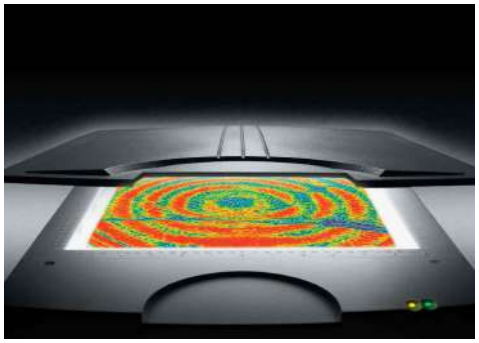


Figure 5. : Topaq® Pressure Analysis System

Finally, all images generated by software can be saved to disk and/or printed out on a Laser or color printer. (Figure 5)

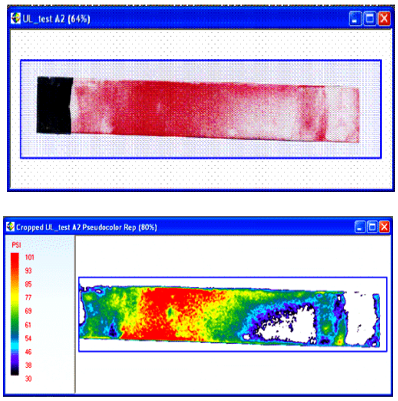
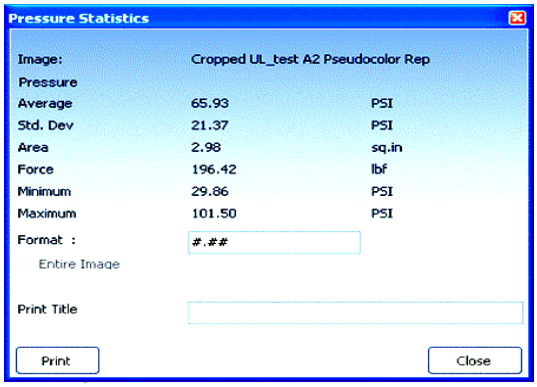
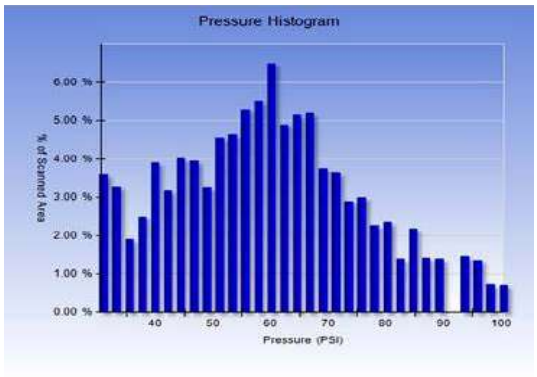


Figure 6. : Software output of pressure sensor films after measurement.





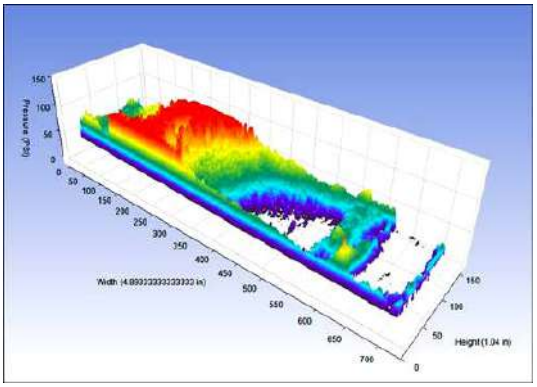


Figure 7. : Software statistic, histogram and 3D reconstruction

A personalized finite element modeling of the pressure was generated from the 3D reconstruction and the histogram of the patient's geometry. (Figure 7.)

The brace treatment was simulated by the application of equivalent forces calculated from the pressure measurements.

After analysis of our measurements, we have got the results of the pressure range between the patient's body and orthosis (Table II.).

TABLE II.

PRESSURE MAXIMUM VALUES FROM MEASUREMENT

PRESSURE AVERAGE [kg/ cm2]		
Measure	**I.**	**II.**
A1	***3,56***	***3,44***
A2	***3,20***	***3,32***
A3	***3,69***	***3,33***
A4	***3,27***	***3,39***
B1	***7,99***	***8,36***
B2	***9,76***	***8,37***
B3	***8,11***	***7,51***
B4	***8,12***	***7,89***
C1	***31,41***	***32,94***
C2	***34,20***	***32,43***
C3	***35,45***	***35,04***
C4	***34,10***	***35,39***

IV. RESULTS AND CONCLUSIONS

Our initial research opened a new view on the construction of a new measurement system. This is a new challenge for researchers, orthopaedists and technicians. Additional research is necessary to get the clear outputs for the field of the diagnostics of scoliosis treatment. Research is moving in a new direction with new methods, technologies and materials.

Nowadays, the new cooperation has started with the Center of Orthopedics and Prosthetics, Kosice. The plan is to measure the contact pressure between the residual limb and prosthetic socket by pressure sensors.

Our second study will be aimed at dynamic measurements using electronic pressure sensors in orthosis during treatment. A new real-time sensor system with the implementation of Sensor Product Company sensors will be designed.

The method of new clinical measurement and evaluation of the results for effective treatment as well as ergonomics, correction features and efficiency for spinal orthoses will be proposed. New technology also for optimalization of mistakes during final tests with patient in laboratory.

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