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The Application of the Matrix Tactile Sensor (MTS) for Measuring Contact Pressures between the Trunk Orthosis and a Patient Body and a Mechanical Testing of the Measuring System

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Abstract Matrix tactile sensors (MTS) as the tactile sensors provide us with information about the measurement object by simply touching the object. Sensitive part of the sensor array consists of the tactile elements arranged in the matrix, which tell us about the distribution of normal forces acting on the tactile elements. Identifying, establishing and monitoring the pressure between the trunk and correcting pad of the trunk orthosis can inform us about undesirable compression actions, progression of the treatment or deformation of the production material of the trunk braces. Identification of the values distribute pressure between the body and pad of the trunk braces serve some information about effects on the human organism.

Keywords: *matrix tactile sensor, MTS, Scoliosis, pad, trunk orthosis, measuring system*

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1. Introduction

The implementation of tactile sensing systems into medicine, prosthetics, orthotics and diagnostics was in the past researched by several research teams. The main object of the research was to determine selected parameters by non-invasive methods. [1] In orthotics was a demand for the progressive replacement of the unnecessary irradiation of the patient by CT examination. [2] Identification of the treatment progression was by the comparison of pressures between the contact correction pad of trunk braces and the patient's body.

In clinical practice was the application of the trunk braces associated with the birth defects in adolescent patients up to the age of 18. Due to the age of the patients, the use of CT (x-ray) examine as the main tool of diagnostics was very limited because of the potential risk from radiation to the human body. [3] For the application of the measurement system to determine the progress of the chosen treatment was needed verification of accuracy of the measurements used for comparison of data about compression actions in the various stages of the carrying trunk braces [4,5].

In the evaluation of the therapeutic effect we needed consider some following parameters and measuring methods, for example: The methods of the assessing comparative measurements, measurement methodology of the exercise acts according to the proposal of the previous research activities was mentioned sensor system subjected to a variety of the test measurements in the laboratory to determine temporal characteristics and the verification of the interpretation and presentation of the measurement data [6,7].

2. Materials and Methods

2.1. The Methodology of the Applications

Determine of the optimum methodology of the work with measuring system, its temporal characteristics and accuracy of the data interpretation verified comparison of the compression actions in the ongoing monitoring of the progress and the setting of the chosen treatment of the scoliosis spine [8,9].

2.1.1. The Tactilus Measuring System

The Tactilus measuring system (Sensorprod USA) was customized as a tool to measure contact pressures between correcting pad of the trunk braces and the patient's body. Sensory pad as a direct measuring tool had a range from 0 to 97.16 kPa, which was a range that could be detected between the body and the brace and the patient body with surface of 400 cm^2 (20 x 20 cm).[10]

Figure 1. MTS system [11]

The measurement system consisted of the five parts (Figure 1) which were sensory pad (sensor) (A) with dimensions 20 x 20 cm, a density of touch-sensitive points 1 per 1 cm^2 and a 400 scan points with a range of 0-724 psi (0 - 729 mmHg, . 0 - 97.19 KPa). Tactilus converter for converting analog signals to digital (B). Notebook (C) and interface cables with dimension of 10 m for a comfortable measuring and USB cable to connect transmitter to a computer (D, E).

CT scanning of measurement matrix was realized by Metrotom (Carl Zeiss Germany) (Figure 2) .

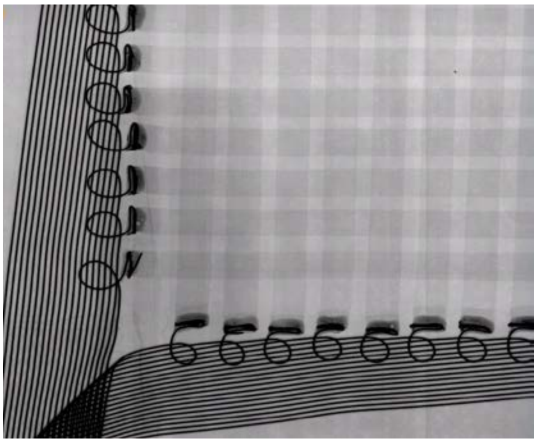

Figure 2. CT scan of the sensor

Table 1. Technical specifications of sensor

Working principle	Piezoresistive / resistive
Pressure range	0.1 to 200 PSI (0.007 to 14.1 kg/cm^2)
Sensory area	20 x 20 cm
Thickness	(0.3 mm)
Thickness of pack	23 x 23 cm
Scanning speed	Up to 1,000 hertz
Spatial resolution	0.04 - 2 mm
Accuracy	± 10%
Repeatability	± 2%
Hysteresis	± 5%
Nonlinearity	± 1.5%
Calibration	Pre-calibrated

2.2. Mechanical Testing

In determining of the testing methodology of the pressure system in the laboratory, we worked with already realized experiments and studies which dealed with the similar testing. [2] The testing methodology was created with regard to the repeatability and reproducibility of the measurement, to eliminate possible measurement errors, using the available hardware (Figure 4).

The measurement of time-load relationship dependence of the continuous load (A). Because of the lack of the results of the measurements and the assumption of changes in the behavior of the signal in time, was the first type of measurement set identification of time course signal time on the continuous load. Measurement of the continual loaded in a pre-selected position of the measuring sensor(B).

During the implementation of the test measurements with the system Tactilus at orthosis were observed variation in the load display with software Tactilus under peripheral parts of sensor pad.

Figure 3. Scanning principle

The proposal of the measurement matrix

Measurement matrix represented the auxiliary measuring device. Its design and converting was designed to ensure accurate measurements with repeated placing the object on the same place and also defined five test positions on the pressure sensor. Production of measurement matrix was realized by 3D printer, Eden 260V (Stratasys Inc. USA) [19] according to designed in format .stl.

Figure 4. Measuring progress

The measurement A

The principle of this kind of the measurement was behavior of the monitoring signal overthe time with continuous load. Weights of 1 and 2 kg were placed on position 5 (center position) in the pre-formed matrix (Figure 4). Scanning programs turns on after the weight was on position. Dynamic action of the weight was not monitored but the progress of the application of the load sensor in time for 20 minutes

The Measurement B

The principle of this kind of measurement was monitoring signal behavior over time with continuous load on 5 position. Weights of 1 and 2 kg were placed in position 1-5 in the pre-formed matrix. Scanning program turned on after the weight was on position. Dynamic action of the weight was not monitored but the progress of the application of the load sensor in time for 1 minute.

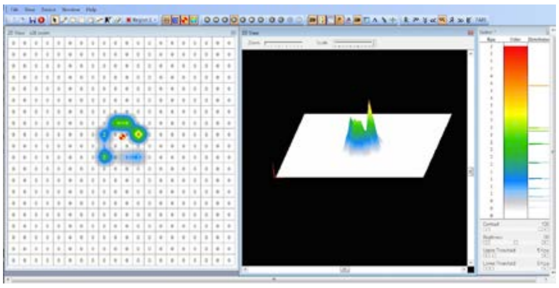

Figure 5. The graphical display of the load

Graphical user interface of the software Tactilus represented on Figure 5, offering information about the location and size of the pressure action, but this information is not sufficient for further statistical processing

2.3. Testing Measurements

Before applications of the measuring system in orthotic practice and various phases of the testing of the braces it would be necessary to create a methodology of the work with measuring system Tactilus and their verification .

The test measurements ministered to establish mentioned the methodologies were implemented in the Department of Biomedical Engineering and Measurement and consisted of the series of the measurements of the contact pressures between the body and the correction pad. The measured subjects did not show indications for corrective treatment with the trunk orthosis, and it was a test measurement which did not serve to determine the exact values of the operating pressures. The measured subjects on the basis of the procedural instruction did individual exercise acts of the chosen methodology applied to the trunk braces.

2.3.1. The Prescribed Method of the Exercise Acts

Unification and determination a uniform method of the measuring compression force appeared to be very important in the progression of the treatment. On the base of the recent research were created the training acts methods that represented the movements which the patient performed daily for self-guided activities. In creating the series of the exercise acts which we related to studies which dealt with biomechanical analysis of the trunk braces measuring of the contact pressure between the body and the brace taking into account movements that a person normally performed during the day because the daily human activities had an effect on the brace, and progress of the treatment.

The subsequent illustration shows the exercise acts performed by the patient during the measurement, which are divided into two categories. Act suitable for taking pressure at all pads - Type 1. Acts for useful when reading pressure on the side and rear pads - Type 2 (Figure 6)

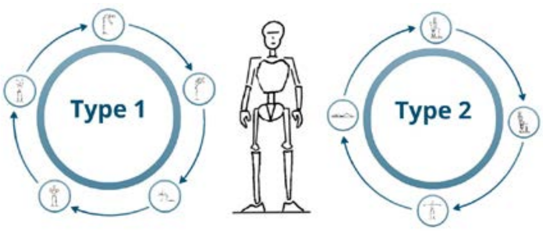

Figure 6. Types of exercise acts

2.3.2. The Determination of the Exercise Controlled Operations

Measured exercises represented movements that everybody uses in dressing, walking or sitting. The purpose of these measurements lay in finding and defining forces with corrective pad acting on the patient's body while the Exercise acts simulated his normal day.(Table 2) This measurement should be done at the stage of testing brace which on detection of pressure is too high for certain activities can prevent the occurrence of the abrasions, or pathologies conditions of the skin, an appropriate adjustment of the brace before its release. Subsequent test runs for a period of wearing the brace will give us information on the course of treatment the scoliosis curve, which is achieved due the compression brace.

Table 2. Exercise acts

A	Standing in the basic position	F	Rotation
B	Escape from the brace	G	Stretched out
C	Bending forward	H	Pull down
D	Kyphosis	I	Sit down
E	Kyphosis on four	J	Lay down

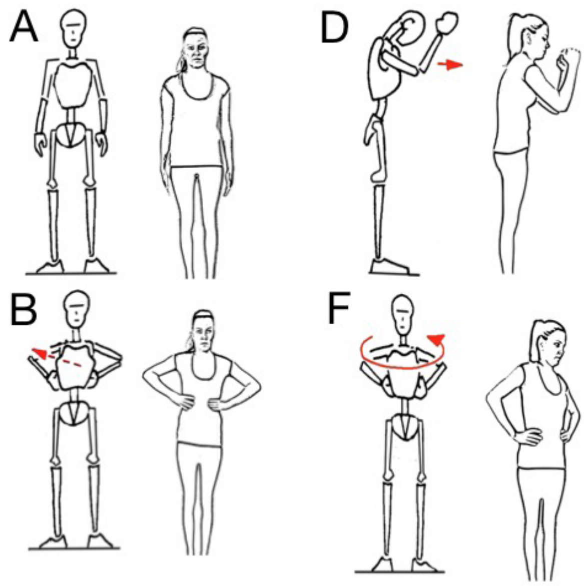

Figure 7. Selected exercise acts

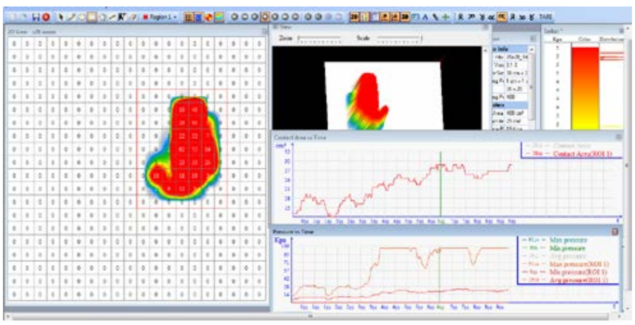

Figure 8. Tactilus software interface

Record of the measurements gave us information about the measurement object and it was possible to apply the editing functions of the software program which recorded adjusted according to the desired output.(Figure 8).

3. Result and Discussion

3.1. Mechanical Testing

In the work with the measuring system was setting a frame rate of 30 Hz. With the image frequency and extent of the measurements it appeared necessary evaluation and selection of the data generated using automated software applications. For this aim in collaboration with the Faculty of Aeronautics, Technical University there were created two software applications.

3.1.1. Time-load Dependence

The waveform chart showed the similarity of the shape of the force in time characterized by a sharp increase in the first minute of the measurement - The leading phase and steady rise curves after 600 seconds measurement (Figure 9).

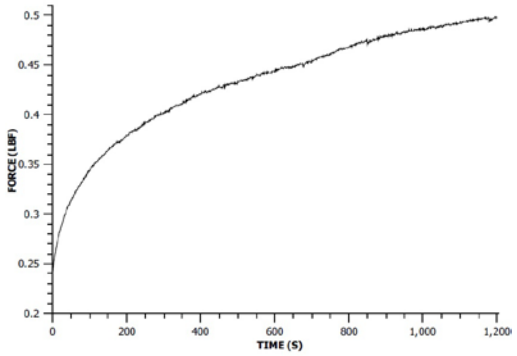

Figure 9. Load-timedependance

The realized measurements were set at 1200 seconds during which the load curve should buoyant. By realized experiment hypothesis was not confirmed about stabilization of the measuring system during the measurement (Figure 10).

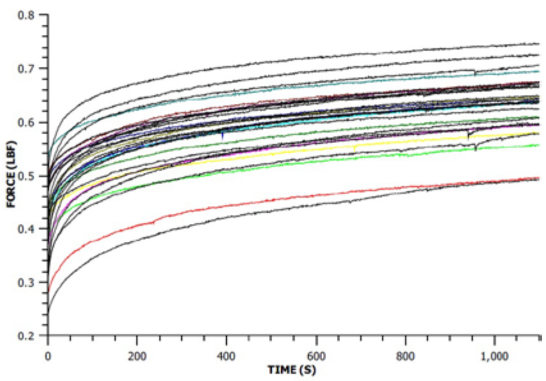

Figure 10. Load in time of 30 measurements

The nature of the curves depicting the history of the force in time after the subjective assessment of the observed shape similarity. For verifying the hypothesis and to define precisely the waveform display load was determined the comparative method.

3.1.2. The Mathematical Definition of the Measurement

Ambiguity graphical outputs of the measurement showed us a need for the using the mathematical regression techniques to compare different measurements .

These methods included the trendcurvesdrawing during the measurement, approximation of the measured values of the polynomial of the least squares (Figure 11).

Second order polynomial regression

$$y = ax^2 + bx + c \qquad (1)$$

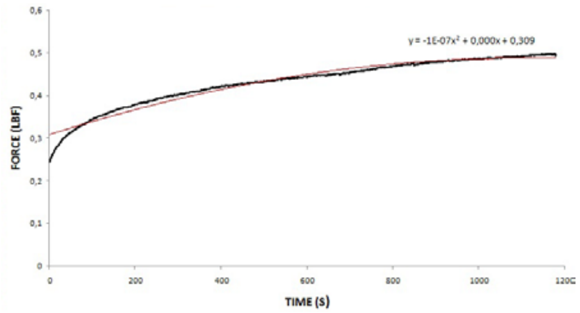

Figure 11. Applied regresionon load in time

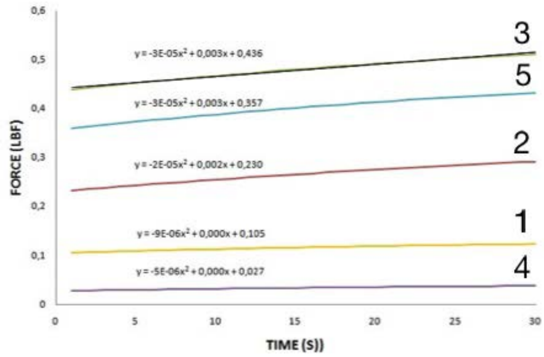

Figure 12. Applied regression on load in 5 places

Statistical processing of the individual parameters of the polynomial equations were developed the reference equations with parameter values equal to the median of 30 measurements.

Measurement B told us presumption of the unequal interpretation of the load in peripheral locations of the sensory pads. Individual curves on Figure 12 presented the time course of load on 5 measuring points pads during the first 30 seconds of the measurement. Mathematical analysis of measured values were confirmed upward trend of signal. Non-linear behavior was observed in parameter C-start parameter determining start positioning of curve.

3.2. The Clinical Application

Measurement was carried out in the workplace of The Prosthetic Center in Kosice in the process of testing the trunk orthosis for scoliosis treatment (Figure 8).

Figure 13. Clinical applications of Tactilussystem

4. Conclusions

Identification of the values distributed pressure between the body and pad of the trunk braces served an information about effects on the human organism. Excessively high pressure values at the interface body - orthosis might indicate in testing time of the brace skin wounds and pressure sores on congested areas, while low pressure tell us about bad function of the brace and the insufficient corrective action. Continuous monitoring of the pressure values during treatment with trunk braces can provide information about its progression. Methodology of measurement consists of the series of the acts necessary for the proper implementation of the repeatable measurement. The object of measurement is a measure of the exercise operations. Designed exercise is the series of the movements that a person performs in a typical day, and the exercise can be supplemented by specific movements according to the individual interests of the patient. The results of these measurements is data about the values of contact pressure at the interface body - orthosis them in a graph of daily activities. In the future, such information which was used in the diagnosis of the scoliosis treatment using on-line monitoring system of the pressure, which should record the pressure during all phases of wearing the trunk braces.

The results of the comparative measurements on the positions were intended to establish the impact of the placing the burden of the representation of the measurement results. The comparison was carried out with the hypothesis that the correct positioning of the load is in the middle of the sensory pads. Results of the analysis confirmed the working hypothesis of the different representation of the results by measurement system according to the location of the loading. Found that the situation can be attributed to the architecture of the sensory pads. Further research dedicated to diagnostic applications of the pressure measurement systems operating in a continuous pressure orthotics may be aimed by creating the wireless online measurement system applicable to continuous measurement of the compression actions.

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References

[1] Herrán,J et al.: Flexible and large area pressure sensors for human-neuroprostheses and human-neurorobotic interface assessment. In: Microsyst Technol. 2012, no. 542, s. 1155-1161.

[2] Park, Y.L et al.: Bio-inspired Active Soft Orthotic Device for Ankle Foot Pathologies In: Intelligent Robots and Systems (IROS). 2011.

[3] Wong, M. S. – Evans, J. H.: Biomechanical evaluation of the Milwaukee brace. In: Prosthetics and Orthotics International.1998, s. 54-67.

[4] Chou, Wen-kai et al.: Using Finite Element Method to Determine Pad Positions in a Boston Brace for Enhancing Corrective Effect on Scoliotic Spine: A Preliminary Analysis. In: Journal of Medical and Biological Engineering. 2010, s. 29-35.

[5] Clin, Julien et al.: Biomechanical study of the Charleston Brace for the Treatment of Scoliosis. In: SPINE. vol. 35, 2010, no. 19, s. E940-E947.

[6] Tiwana, Mohsin et al.: A review of tactile sensing technologies with applications in biomedical engineering. In: Sensors and Actuators. 2012, s. 17-31.

[7] Antonelli, M.G. et al.: AN INNOVATIVE BRACE WITH PNEUMATIC THRUSTS FOR SCOLIOSIS TREATMENT In: Design & Nature and Ecodynamics. vol. 5, 2010, no.4 , s. 354-367.

[8] Fader, Mandy et al.: Effects of absorbent incontinence pads on pressure management mattresses. In: Journal of Advanced Nursing. 2004, s. 569-574.

[9] Hatzivasiliou V, Tzafestas SG. Analysis and design of a new piezoresistive tactile sensor system for robotic applications. J Intell Robot Syst 1994;10:243-56.

[10] Sensor Products INC. Tactile pressure expert, Internet: http://www.sensorprod.com/static/biomechanics.php (2.10.2012).

[11] Hudák, R et al. The use of matrix tactile sensors (MTS) for diagnostics of the efficiency of production, testing and application of a trunk orthosis. In:13th IEEE International Symposium on Computational Intelligence and Informatics. 2012.