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VIRTUAL INSTRUMENTATION AND CANTILEVER BEAM TYPE TRANSDUCER WITH STRAIN GAUGES FOR MEASURING THE DISLODGING FORCES OF REMOVABLE DENTURES OR PALATAL PLATES

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Abstract: The TensoDentar is a complex measurement system of dislodging forces for complete dentures or palatal plates. An original strain gauge force transducer (SGFT) and virtual instrumentation in NI and LabVIEW environment are used conforming to a rigorous clinical protocol to evaluate the efficiency of two surface treatments (sandblasting and plasma treatment) on complete denture base materials. The present work has the unprecedented goal to achieve *in vivo* comparison of the two techniques. First experimental results obtained are presented and interpreted.

Keywords:, force transducer, strain gauges, cantilever beam, virtual instrumentation**.**

1. INTRODUCTION

The TensoDentar measuring system is mainly intended to evaluate the dislodging forces of complete upper dentures, estimated at F_{max} = 5 N (about 500 grams force). Having in view the use of this experimental model also for testing detachment of palatal plates, which occurs at only a few tens of grams-force, the wide range of loads requires the creation of a special force transducer, the most appropriate being that based on a flexible beam embedded at one end and subjected to bending at the other end, with two resistive strain gauges as sensing elements [1].

Strain gauges were previously used in measuring this type of forces in connection with analogic measuring equipment: oscilloscope or pen chart recorder, but the involvement of digital environment substantially increases the measurement precision. The NI hardware and associated LabView software developed on MS Windows platform allow the conversion of analogic inputs into digital signals and their improved analysis by virtual instrumentation.

We initially projected the attachment of the tensometric force transducer to a horizontal fixed arm (Fig. 1,a). During the first tests we found it is very hard to adapt this configuration to the perpendicular dislodging principle in the gravity center of each plate. The initial setup increased the time of preparation which altered the status of the interfacial salivary film, and therefore we abandoned the fixed arm and decided to use this transducer independent of its supporting arm, due to its handle which can be operated by a human operator, after proper training (Fig. 1,b).

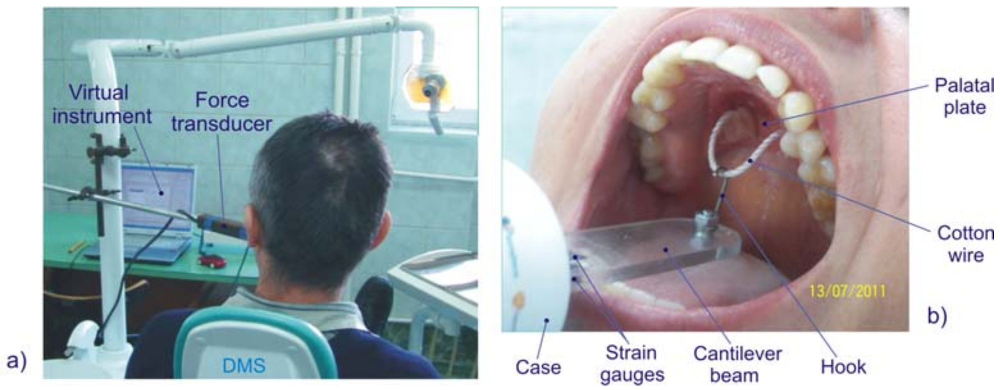

Fig. 1. a) Overall view of the TensoDentar equipment. b) Strain gauged cantilever beam used as force transducer for dislodging a palatal plate.

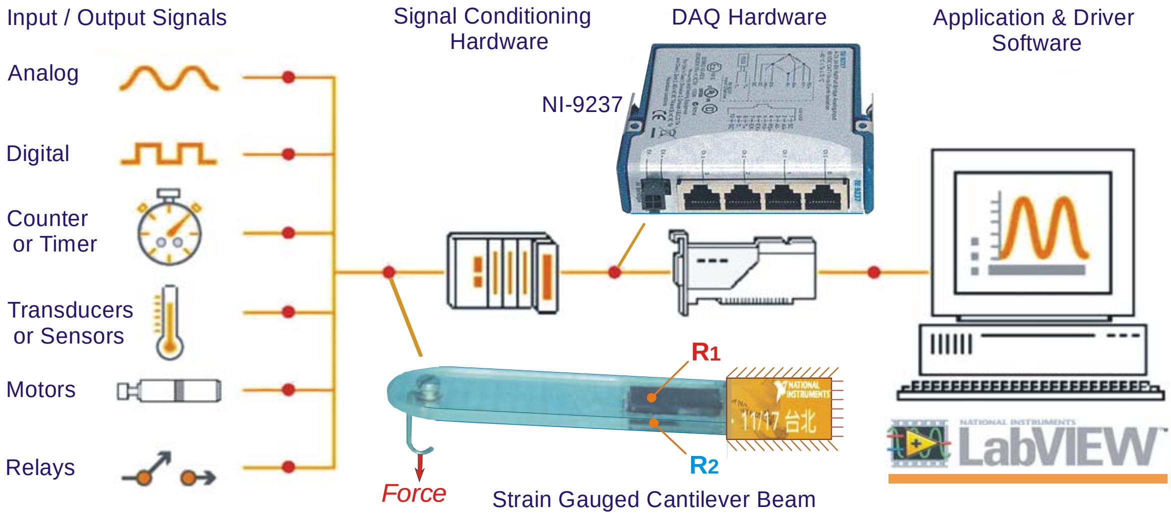

Fig. 2. DMS strain gauge force transducer (SGFT) integrated in the NI hardware and LabVIEW software.

The relatively low loads and the limited oral space available determined the choice of a more elastic material than steel or aluminum, namely Plexiglass (polymethyl methacrylate), which has an elasticity modulus $E = 2.3…3.3$ GPa, depending on the chemical composition and temperature.

2. EXPERIMENTAL SETUP

The block diagram of experimental setup includes the following main components (Fig. 2):

- Force transducer of cantilever beam type with strain gauges (SGs);
- Analogic data acquisition board (including the signal conditioner), part of the “architecture” of the NI integrated solutions;
- Desktop computer or laptop.

The elastic lamella, having the “active” length $\ell = 54$ mm, breadth $b = 20$ mm, height $h = 4$ mm, is equipped with two epoxy strain gauges type 10/120 LB 15, glued with Z 70 bond and protected with SG 250 putty (Hottinger); it constitutes the “heart” of the TensoDentar measurement system.

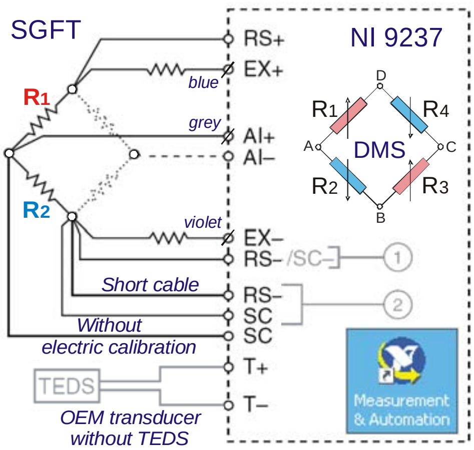

Fig. 3. SGs wiring scheme in Wheatstone bridge.

One can notice the sense and colour conventions for the strain gauges connected in half Wheatstone bridge (Fig. 3), where resistors are symbolized with a zigzag line (American) or a rectangle (European):

- The electrical resistance R_1 of the strain gauge located on the upper side increases by bending the cantilever and is represented by a “warm” colour: *red*;
- The electrical resistance R_2 of the strain gauge located on the lower side decreases by bending the cantilever and is represented by a “cold” colour: *blue*.

The NI-9237 module [2] contains 4 channels with analog inputs in Wheatstone bridges and 24-bit resolution Delta-Sigma type analog-to-digital converters. Only one analog channel is used together with its built-in signal conditioner. This module is mounted onto the NI-9172 chassis [3].

Its Hi-Speed USB 2.0 interface simplifies the mode in which the users control the peripherals and data transfer, offering the following advantages: “plug-and-play” operation, robustness and easy-to-use. The global picture of the measurement system is given in Figure 4.

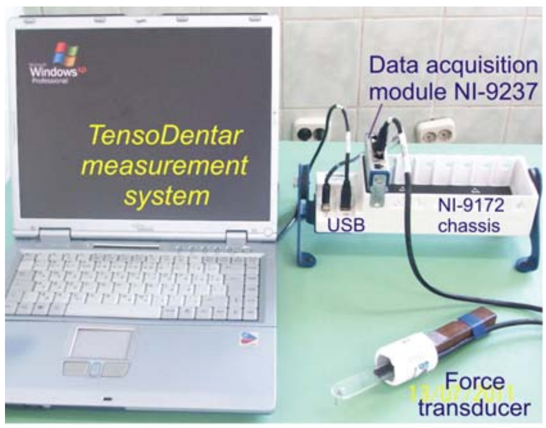

Fig. 4. TensoDentar computerized measurement system.

The laptop, which constitutes its "brain", is Windows-operated and utilizes the LabVIEW™ program, agreed by National Instruments. The entire application, starting with the prototype force transducer DMS and culminating with the dedicated software, is a typical OEM (original equipment manufacturer) one and enjoys all the advantages offered by the virtual instrumentation.

3. VIRTUAL INSTRUMENTATION

The virtual instrument makes use of the force transducer for sensing the physical quantity to be measured and analog-to-digital conversion module, but beyond these all processing and analysis of measured values, storing and transmission towards the human user are performed by the computer [4].

The STRAIN configuration was selected for the measurement chain (Fig. 5), which is better fitted with the phenomenon than the alternate setting in mV (Voltage Output).

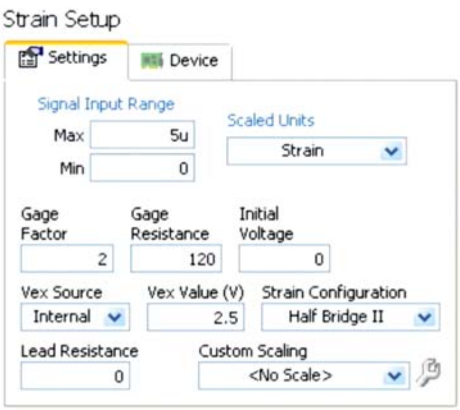

Fig. 5. Channel settings for strain gauge force transducer.

Here are the significances of the text appearing in the graphical "windows":

- Signal Input Range: unipolar signals, corresponding to the bending of strain gauged cantilever in a single direction, with minimum value 0 and maximum one of 5.000 μm/m (written as 5u);
- The chosen strain gauges have (in American spelling) Gage Factor = 2, Gage Resistance = 120 Ω and do not require an Initial Voltage;
- The internal power source of the DAQ module is utilized, choosing minimum value (U_A = 2,5 V), which ensures sufficient sensitivity of the measurements;
- An important adjustment is the Strain Configuration of the Wheatstone bridge, programmed as a type II half-bridge, which means that both strain gauges are "active", i.e. they are bonded along the axis of the cantilever beam; by its bending under the applied load, strain gauge R_1 is extended while strain gauge R_2 is shortened in the same ratio. This differential setup ensures a doubled sensibility as compared with using of a single strain gauge (on the upper side of the lamella).
- The measurement cable being considered short (2 meters), its resistance compensation is not necessary, so the correct setting is Lead Resistance = 0.
- Custom Scaling is not necessary; the system works directly in engineering units of specific deformation: microstrain (μm/m).
- Due to the static character of the application, it is not necessary to set the maximum speed for the DAQ module. The operating mode uses continuous samples and a buffer having the rate of 10 kHz, with 1000 samples to read.

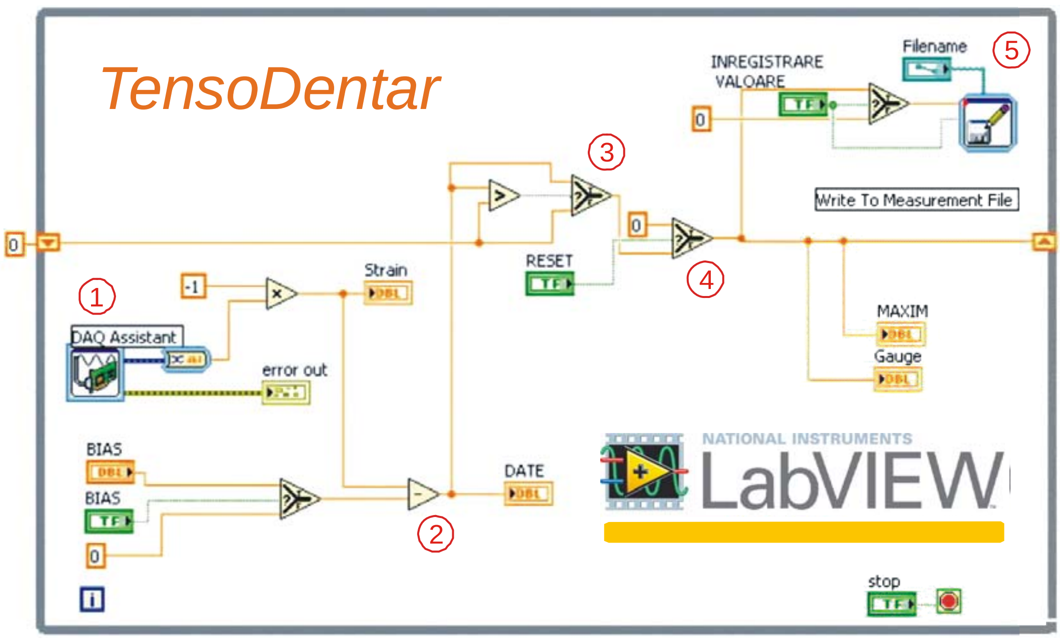

Fig. 6. Logic algorithm of the TensoDentar dedicated LabVIEW application.

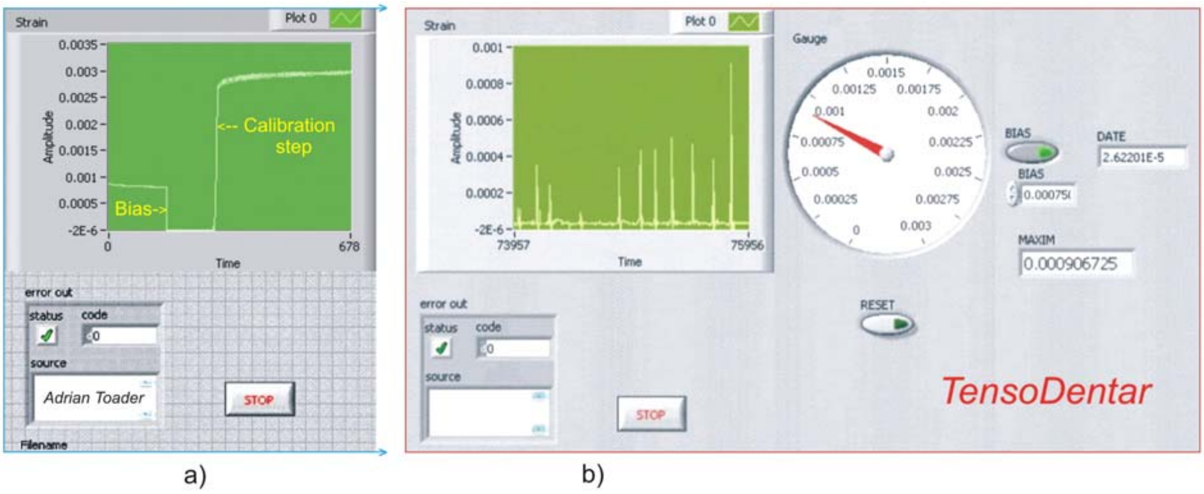

Fig. 7. a) Part of the frontal panel during calibration. b) Frontal panel during a series of measurements of palatal plates dislodging forces. The panel contains the BIAS and RESET buttons, as well as the path to the recording file.

Experimental recordings of the strain were done using the NI-9237 data acquisition board, a dedicated hardware for strain measurement, and the associated LabVIEW 2010 software [5]. As any graphical programming environment, our Tenso-Dentar application contains two parts: the block diagram and the front panel. Description of the software and of the NI-DAQmx driver for the carrying out of measurements and control of associated peripherals is given as follows.

The block diagram shows a few interconnected blocks/functions which represent the program algorithm (Fig. 6). In our application, the block from the step # 1 defines the acquisition task and its parameters (bridge type, acquisition mode and sampling rate). The output of this block gives the strain value as measured with the Wheatstone bridge. This value is then multiplied by –1 to have a positive strain for the actual bending sense of the cantilever beam. In step # 2 of the block diagram the BIAS value of the strain is removed in order to balance the measurement channel. The next part of the program, step # 3, retains in a shift register the maximum value of the strain at which the cantilever beam was bent during the experiment. On step # 5 this maximum value is recorded in a file, after which the shift register is cleared to zero (RESET), step # 4, in order to keep the next experimental value of the maximum strain.

On the virtual instrument front panel for signal acquisition and data processing (Fig. 7,b), the strain variation in time is represented on a chart (plot), and the maximum value of the strain is simultaneously displayed on a dial gauge as well as on a numeric indicator (readout).

4. EXPERIMENTAL RESULTS

On the calibration diagram (Fig. 7,a), obtained by removing the 683 grams standard weight (average value of determinations made on several digital scales) from the bent lamella hook (Fig. 8,a), the specific skip can be noticed as a "step" and the value of 3000 μm/m appears on the oscillogram, as Strain Amplitude: $\varepsilon = 0.003$.

The exact sensitivity coefficient, determined before each experiment by directly comparing the microstrain indication read with the weight in grams-force, allows relating the maximum indication of each test to the force required for the detachment of palatal plates (Fig. 8,b) or upper dentures.

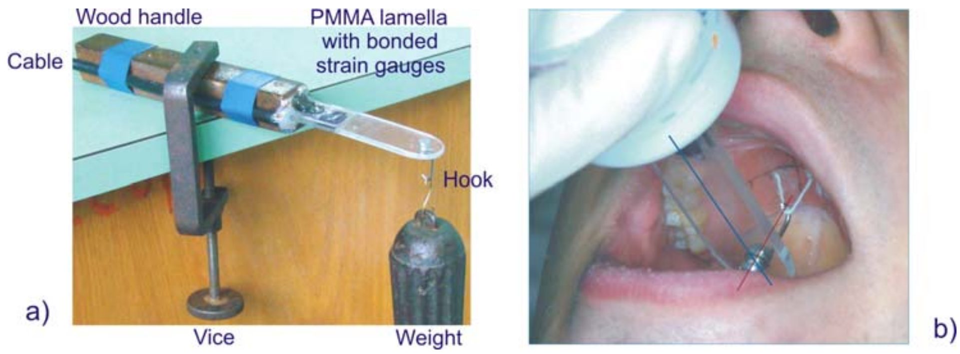

Fig. 8. The strain gauge force transducer (SGFT) in two situations: a) gravimetric calibration with a dead weight. b) during the traction force *F* applied in the geometric center, normal to the palatal plate.

The clinical testing protocol has to be precise, homogenous and reliable [6]. Our objective was to fabricate for each subject two palatal plates which were used to determine the retention force induced only by the salivary film. One set of plates was sandblasted using the dedicated device Point II (Barth, Germany), loaded with 110 μm aluminium oxide particles at a pressure of 2.5 bars. The other set of plates was treated with low pressure plasma in argon medium using a discharge chamber (Bell-Jar configuration).

We executed 35 measurements for each plate, excluding the first ten minimum and ten maximum values, *before* and *after* surface treatment, and diminishing in this way the measurement errors induced by the operator's technique. The remaining 15 values were statistically analized using SPSS (Statistical Package for the Social Sciences) for Windows 2010. Then, descriptive statistics were performed and the results obtained for five subjects (A…E) are presented in synoptic tables and in comparative diagrams, like in Figure 9.

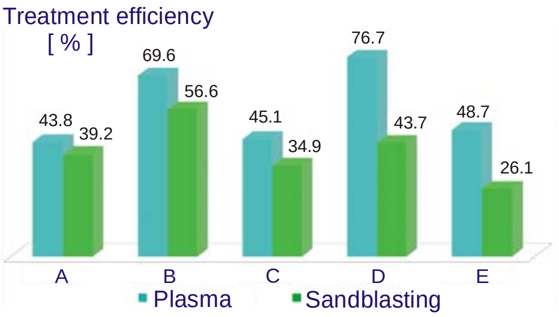

Fig. 9. Comparison between the percent values of the retention efficiency for palatal plates after sandblasting (on the right side) and, respectively, plasma treatments (on the left side for each patient).

Our intention was to evaluate the plate performances before and after the specific surface treatment applied. Plasma treatment increases the retention (43.8 to 76.7 %) more than sandblasting (26.1 to 56.6 %) for every subject.

In addition, we did not found a direct relation between area and retention, underlining the role of interposed salivary film regarding the retention of experimental palatal plates.

5. CONCLUSIONS

The complex measurement system TensoDentar has been successfully used for the evaluation of dislodging forces for palatal plates, based on an original strain gauge force transducer and virtual instrumentation in NI and LabVIEW environment. Two surface treatments (sandblasting and, respectively, plasma treatment) on complete denture base materials were applied; their effect was presented and interpreted.

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