

Development of a Microtorquemeter for the Evaluation of the Implant Abutment Interface Behavior

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Abstract. This paper presents the initial developments of a prototype device intended to perform measurements of the fastening torque in the range below 1 N.m – hereby denominated microtorque. The device is intended to yield data for analysis of *in vitro* torquing and detorquing experiments, for fixation and removing of abutments in dental implants and implants in artificial bones. The analysis of the data acquired allowed the authors to observe characteristic fingerprints or signal signatures associated to the type of abutment or implant under experimentation as well as of the mechanical prototype characteristics. In this paper, two different systems of abutment and implant were analyzed. The correlation between the phenomena associated to the signal fingerprints indicate that the developed measurement protocol may be extended to other implant / abutment systems. The authors suggest that the insertion and removal torque curves evaluated in this study would facilitated the correlation between the abutments stability in actual patients and the dynamical behavior under masticatory function.

Introduction

The control of the fastening torque of threaded elements (nuts, bolts, etc.) is an important manufacturing factor in industry equipment. This is due, if properly used, to the insurance of the repeatability of the tightening of fasteners, in the assembly lines of machinery and equipment. These types of equipments are readily available and used in the automation sector. Besides this, there are areas where the tightening of threaded elements should be performed with equal care, but with very low torque values, to avoid damage of parts. In 2002, Standlee et al[1] and Tan & Nicholls[2], rated the degree of inaccuracy in the microtorque wrenches used in the installation of implants. The data showed a 15% to 48% change of the desired microtorque.

This study aims to present the development process of a prototype device for measuring microtorques for the insertion and removal of threaded elements, such as those used in the field of dental implants. The choice microtorque subject was due to the scarce available literature about it, making it a very appealing subject. The dental implant consists of two parts, a device called an implant, which may be cylindrical or conical in shape with a central cavity and internal female thread, wherein the second device, the abutment, is fixed. Externally the implant has threads, which serve for locking into the bone. This group serves as a support structure for the dental prosthesis. The abutment should be set to the implant in an accurately and stable way, to withstand masticatory forces, see Fig. 1a and Fig. 1b.

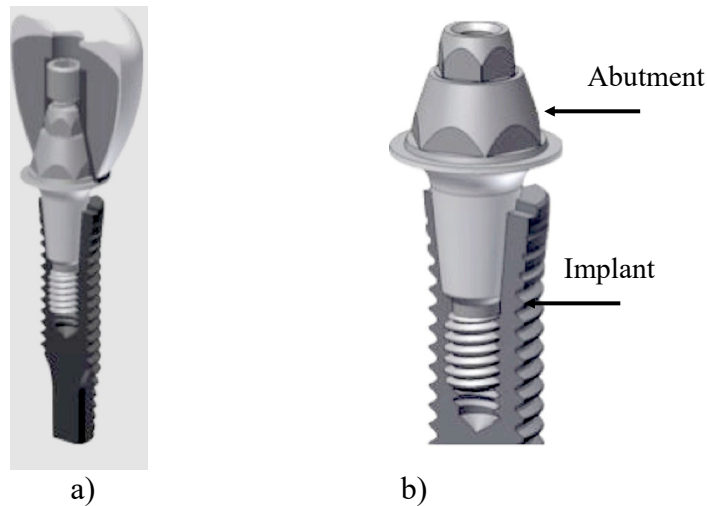


Fig. 1. a) Illustration of three parts of a dental prosthesis: implant, abutment and dental crown. b) A higher magnification illustration focusing on the adaptation detail of the device

Experimental

The authors present the methodology applied in the development of a prototype device to be used in the studies of microtorque observed during for a set of experiments of torquing and detorquing of prosthesis abutments during *in vitro* experiments.

The project for microtorque measurement prototype device was planned with the following sections [3] layout and design; microtorque bar project and extensometry electronics; microtorque bar precise linear movement; mechanical drive of the sample holder; step motor programmable electronic interface.

The principle of operation of the prototype is as follows. A sample holder is turned by means of an electronically controlled stepper motor while the abutment is linearly inserted in the implant fixed to the holder. The prototype device projected and constructed is shown in Fig. 2. From left to right one can see the mechanical drive (a gear set provides a 19.58:1 reduction of the rotation from a unipolar stepper motor), the drive shaft and bearings, a flex joint and a sample holder. The axis of the apparatus was aligned from the drill chuck to the microtorque bar (which holds the strain gage) to a 0,01 mm/m linear precision. The microtorque bar is fixed to a precision linear bearing and rail, which allows for a free and precise linear movement of the abutment or implant when it was being inserted.

Aluminum alloy AISI AA 5052 was used the in the construction of the microtorque bar described in this article. The known value for the elastic modulus of the alloy is 70.0 GPa [4]. Due to the low level voltage observed in the strain gage response to the applied microtorque, a National Instruments CompactDaq[®] chassis was chosen to set up the data acquisition system. A NI 9235, 8-channel quarter-bridge strain gage module, allows full 10 kS/s (kilo-samples per second) data acquisition with 24 bits resolution and was connected to a strain gage type KFC-10-D16-11.

The data acquisition system is completed with the LabView[®] graphic and programming environment. A Bessel filter was applied to a 1 MHz input signal that was then file logged for further analysis.

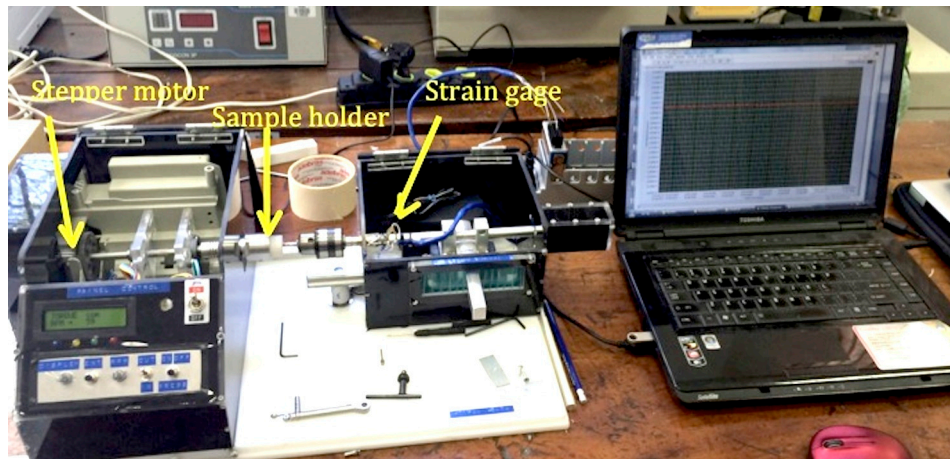


Fig. 2. Image of the prototype device showing the main parts. The mechanical driver, torque sensing and data acquisition area shown

An Atmel AVR microcontroller was chosen as the stepper motor driver controller interfaced by a Schotky bridge. A LCD displays the main information of the operation, and toggle switches and potentiometers allows for the control of rotation.

The commercially “Pross Dabi Implantés®” implants were used in the experimental being implanted in polyoxymethylene rods due to its stiffness, low friction and excellent dimensional stability. These are Morse tapered type abutments of two different systems: index abutment and solid abutment. The choice was made to provide torqueing data on two significantly different abutments systems. It is important to note that in the solid abutment system, the contact surface formed between the Morse cone abutment and the implant is a shear frictional, because the screwed tip of the abutment is part of the body as the cone itself. For the index abutment system, a bolt is placed through the cone, pressing it into the implant as the screw is tightened.

A calibration procedure was devised, using a set of known weights being hang at the tip of a bar with know length, the horizontal deflection angle was recorded for each weight together with the signal generated in the microtorque bar strain gage [5]. The results are summarized in Tab. 1. In Fig. 3 the microtorque bar strain gage signal mV/V is plotted against the applied microtorque Ncm and is used as a calibration curve for the prototype device at the time of the experiments the uncertainty bars both for the applied microtorque and the strain gage signal cannot show up due to its small size.

Table 1. Applied torque Ncm against microtorque strain gage bar signal mV/M

Applied torque Ncm	Measured torque uncertainty Ncm	Measured signal mV/V (assigned to the torque bar shear deformation)	Measured signal uncertainty mV/V
13.19	0.19	0.0006540	0.000005
15.77	0.08	0.0006520	0.000005
23.82	0.12	0.0006410	0.000005
31.86	0.16	0.0006310	0.000005
39.95	0.20	0.0006205	0.000005
47.90	0.24	0.0006100	0.000005
56.03	0.28	0.0006010	0.000005
64.10	0.32	0.0005905	0.000005
72.15	0.36	0.0005805	0.000005
80.68	0.40	0.0005700	0.000005

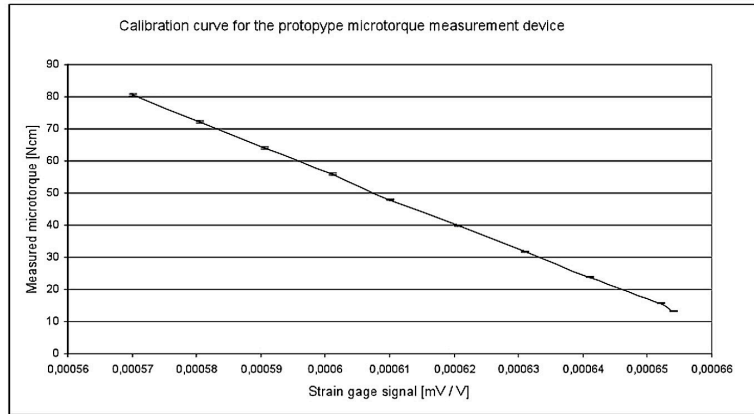


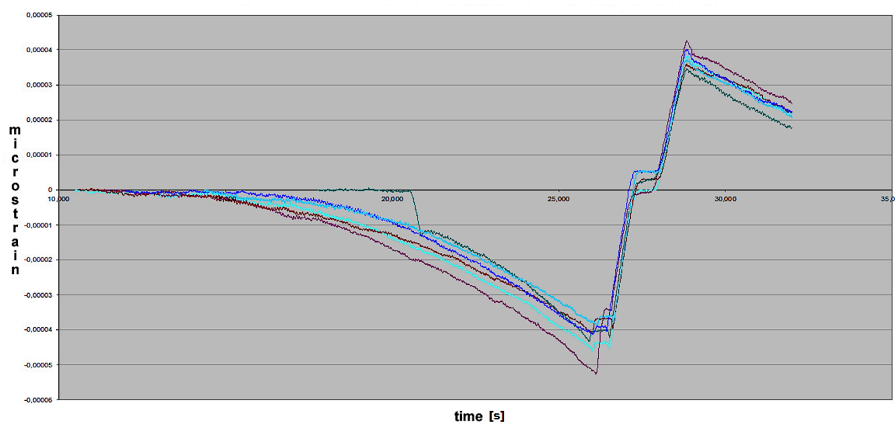
Fig. 3. The microtorque bar strain gage signal mV/V is plotted against the applied microtorque Ncm. This data was used as a calibration curve for the prototype device

For the sake of investigation of the elapsed time evolution of the microtorque behavior during the insertion and removing of the abutments, two sets of experiments were planned one for each type of abutment. The experiments run continually and the torquing and the detorquing of six solid abutments and seven index abutments were recorded. The maximum applied microtorque was 20 Ncm or 0.000645840 mV/V signal from the strain gage on the microtorque bar.

Results and Discussion

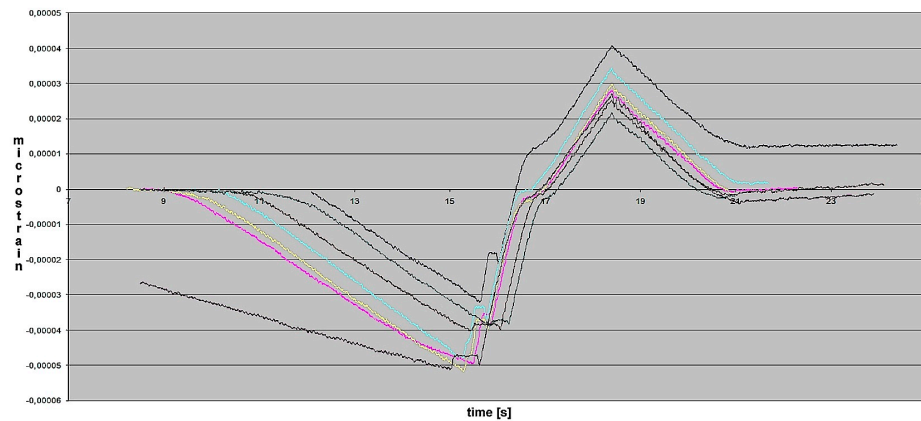
The results of the two sets of experiments of torquing and detorquing are summarized in Figs. 4 and 5. The results clearly show a signal fingerprints for each type of used abutment.

The observed discrepancies of maximum applied microtorque in the abutments for its insertions, chosen as 20 Ncm, is due to a time lag system for the rotation inversion, not due to any mechanical error of the project. For the solid abutment system, the microtorque discrepancy was 11.5 % and the microdetorque discrepancy was 7.8 % while for the index abutments system the same uncertainty were 12.0 % and 12.9 %, respectively.



Quantity	Value	Quantity	Value
Average minimum strain gage signal mV/V	-4.33634 E-05	Average maximum strain gage signal mV/V	3.77092 E-05
Standard deviation mV/V	4.9834 E-06	Standard deviation mV/V	2.93986 E-06
Average microtorque Ncm	-65.48	Average microdetorque Ncm	56.94
Standard deviation Ncm	7.52	Standard deviation Ncm	4.44

Fig. 4. Evolution of torquing and detorquing curves for the solid type abutment. Average values and the standard deviation are shown in the table



Quantity	Value	Quantity	Value
Average minimum strain gage signal mV/V	-4.60225 E-05	Average maximum strain gage signal mV/V	2.71244 E-05
Standard deviation mV/V	5.54089 E-06	Standard deviation mV/V	4.27281 E-06
Average microtorque Ncm	-69.49	Average microdetorque Ncm	40.96
Standard deviation Ncm	8.37	Standard deviation Ncm	6.45

Fig. 5. Evolution of torquing and detorquing curves for the index type abutment. Average values and the standard deviation are shown in the table

From the analysis of the curve in Fig. 4 for the solid type abutments, the authors observed that there is a typical signal fingerprint for this kind of abutment and that the curve may be divided in three different zones. The microtorquing zone is characterized by a non-linear behavior between microtorque and time. A transient zone that occurs after the rotation sense inversion and the detorquing zone. The non-linearity observed in the microtorquing zone is believed to be caused by the friction between the two conical surface of the implant and the abutment. The transient zone has the same behavior as the one observed for the index abutment indicating that this behavior is exclusively associated to the prototype device intrinsic movements. At first, a reduction of the microtorque soon after stop of the microtorquing movement is believed to be associated to the spring back of the steps of the stepper motor and to the gearbox backlash. A horizontal period may be observed and represents the time between the stop of the microtorquing movement until the beginning of the microdetorquing movement. Follows two linear lines that are related to the intrinsic behavior of the elastic coupling between the drive shaft and the sample holder as formerly explained, and a characteristic of the prototype device. The detorquing zone of the curve shows a peak that is associated to the removal of the friction interference between cone surfaces of the implant and the abutment followed by the final detorquing of the screwed tip of the abutment.

For the index system of abutments, the curve is shown in Fig. 5 and exhibits the characteristic signals fingerprint. The transient zone has the same behavior observed in the solid system of abutments again associated to the mechanical characteristics of the prototype device. The microtorquing characteristic of the index abutment is mainly linear and is associated to the microtorquing of the screw. The slight non-linearity of the microtorquing zone is due to the increasing effort needed to insert the abutment into the implant but is far from the observed non-linearity in the solid abutment torquing behavior. The microdetorquing zone does not exhibit the characteristic peak observed in the solid abutments characteristic signal. The curve is almost linear because the abutment stays fixed in the implant during the screw microdetorquing unlike the observed behavior of torquing zone.

Conclusion

The project and building of a prototype device under development and presented at this paper, yield an equipment capable of measuring microtorques for dental implant and abutment insertion analysis and protocol evaluations.

The measurement reproducibility was evaluated and showed a high dependence of the environment and device temperature. The device signal fingerprint is characteristic of the assembly indicating that the calibration procedure must be carried out after any geometrical or mechanical modification.

The development of the measurement process allowed the authors to analyze the mechanical interaction between the implant and the abutment for two different systems. The correlation between the phenomena associated to the signal fingerprints indicate that the developed measurement protocol may be extended to other implant/abutment systems and for other implants manufacturers.

Finally, the correlation between the abutments stability in actual patients and the dynamical masticatory behavior will be facilitated with the developed prototype device.

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