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Initial stability analysis of spine pedicular screws using modal analysis method

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Abstract

The aim of this study was set to propose a new approach for biomechanical assessment of orthopaedic metallic bone screws using modal analysis method, as utilized in predicting the fixation strength of the dental implant.

Introduction

- Bone screws are being used in many applications. As one example, pedicle screws are widely used to obtain rigid internal fixation of the spine for treatment of several severe spinal deformities. Loosening is a major failure mode of screws [1].
- Screws can be evaluated using a variety of different methods (Fig. 2). Pull-out and insertion torque tests are widely used in biomechanical evaluation of the stability of pedicle screws. It has been shown that peak pullout force depends on several parameters such as screw design, insertion technique, bone quality, and test conditions.
- Modal analysis is currently used to evaluate mechanical primary and secondary stability of dental implants, and it is anticipated that it can be used in orthopaedic and spinal systems, as well. This is a non-destructive method, and it can be repeated for each sample several times. According to this method, each mode of a vibrational system can be stimulated, and natural frequencies can be recorded. These natural frequencies are in relation to stabilities [2].

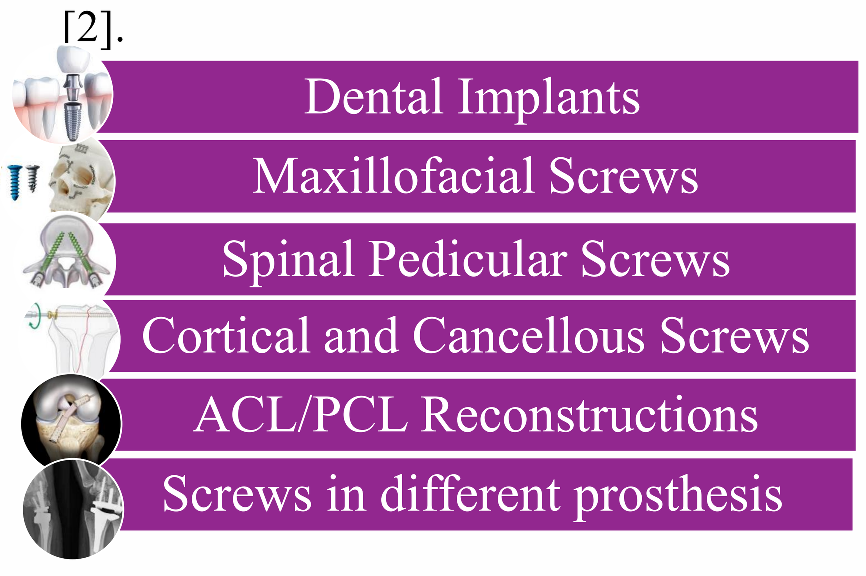

Figure1. Different bone screw applications

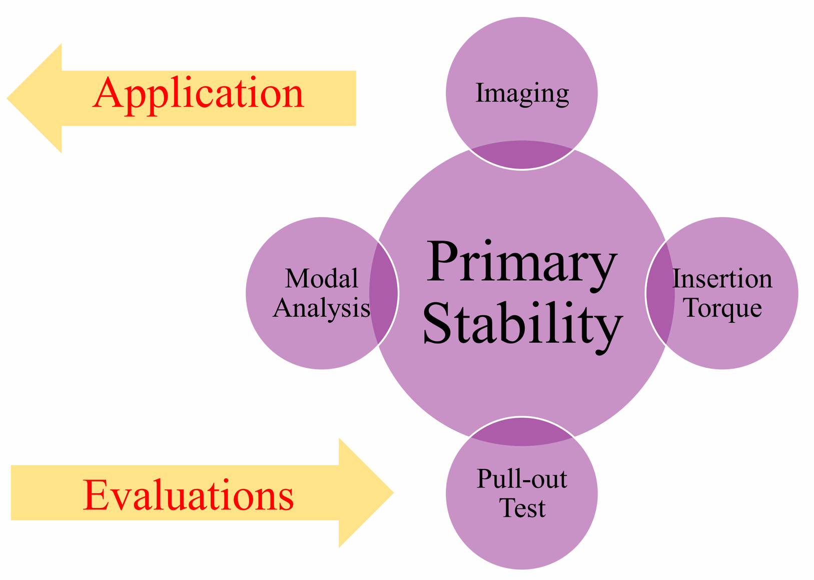

Figure2. methods of bone screw evaluation

Material and Method

Screw Insertion: Four metaphysis portion of two tibial bovine samples (Fig. 3.a) were selected. Five different pedicular screws in term of designs (Fig. 3.b) were selected to evaluate first the effect of thread shape and second the effects of existence of self-tapping features both in conventional pull-out test and modal analysis. The design characteristics were shown in table 1. All screws were inserted in the same insertion depth *i.e.* 10 mm and same orientations according to ASTM F-543-17 [3].

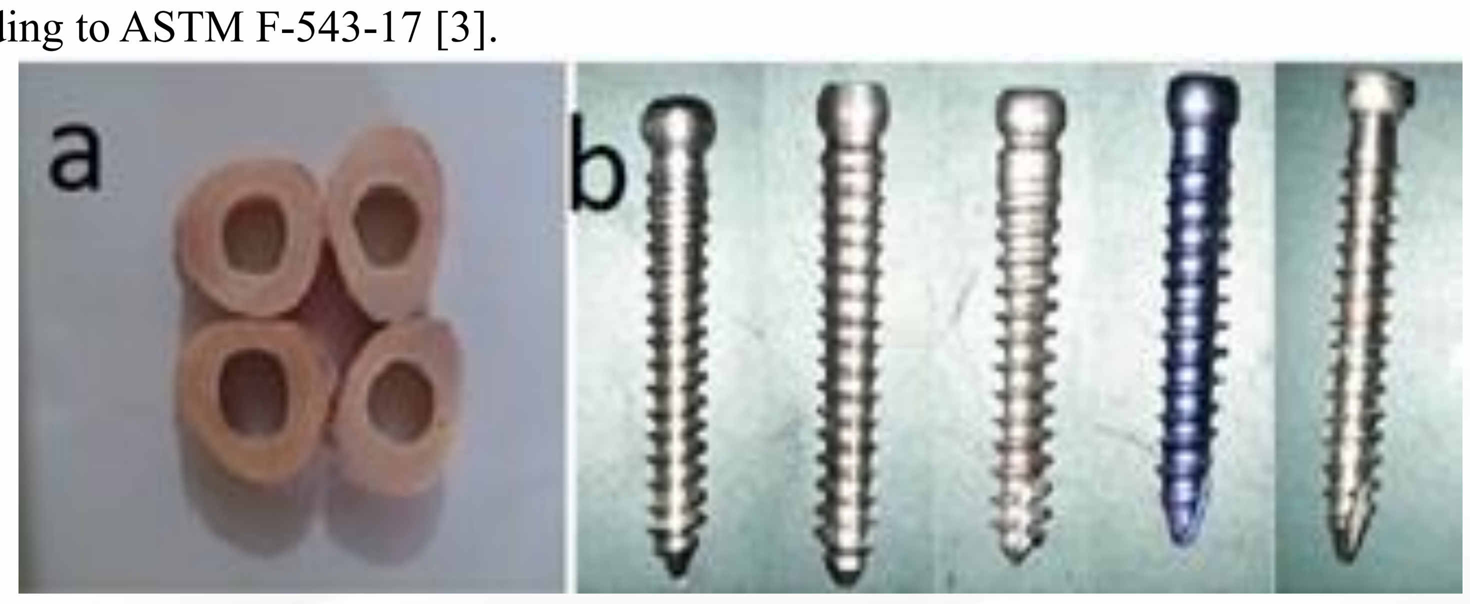

Figure 3: a) Divided cortical bovine samples from tibial portion, b) Screw samples with different thread distribution and specification mostly different in core shape, crest thickness and self-tapping feature

Table 1: Screw specifications with 6.5 mm thread diameter and Cylindrical thread shape

Screw No.	Thread Length (mm)	Crest Thickness	Self-tapping	Core shape	Depth of threads	Weight (gram)
1	50	Constant	Yes	Cylindrical	Constant	4.25
2	44.8	Constant	Yes	Cylindrical	Constant	4.04
3	50.3	Non-Constant	Yes	Conical	Non-Constant	4.57
4	47.6	Constant	NO	Conical	Non-Constant	4.65
5	45	Non-Constant	NO	Conical	Non-Constant	4.59

Material and Method

Modal Analysis: First, impact was applied to the head of each screw. Secondly, the impacting sound was recorded using a simple recording device. The recorded sound was processed in MATLAB R2019 software and using Fast Fourier Transform (FFT), data was converted from time domain into the frequency domain. The location of the peaks illustrated the natural frequencies at different modes. The first peak in this frequency response was selected as the first mode of vibration.

Pull-out Test: The pull-out test was performed according to the ASTM-F543-17, using a uniaxial tensile testing machine (Zwick /Roell, DTM, Germany). Displacement rate was selected 5 mm/min, and data collection was kept on until it was pulled out from the bone completely. Load-displacement data were recorded at a rate of 25 Hz. After the placement of pedicle screw within the bone, the orientation of the pedicle screw and tensile hook manipulated in the coaxial orientation. Then the load cell was zeroed, and the peak pull-out force was recorded for each test case.

Results and Discussion

- ✓ **Maximum natural frequency** and **pull-out force** occurred in the screw number three which has a **conical core and non-constant crest thickness**. The **minimum natural frequency** and **pull-out force** belongs to the screw number two which has **cylindrical core and constant crest thickness**
- ✓ By comparing the screw number one or two with other conical screws this fact can be concluded that **conica**l **screws** have **higher primary stability** than cylindrical ones ($p<0.05$) [4].
- ✓ **No** significant difference between **uniform** and **non-uniform** crest thickness was happened due to comparison of screw numbers four and five (Fig 4).
- ✓ For **self-tapping** feature it can be concluded from the results of screw number three and five that although slight increase has happened in screw number three with self-tapping tip but this increase was not the significant order of magnitude [5].

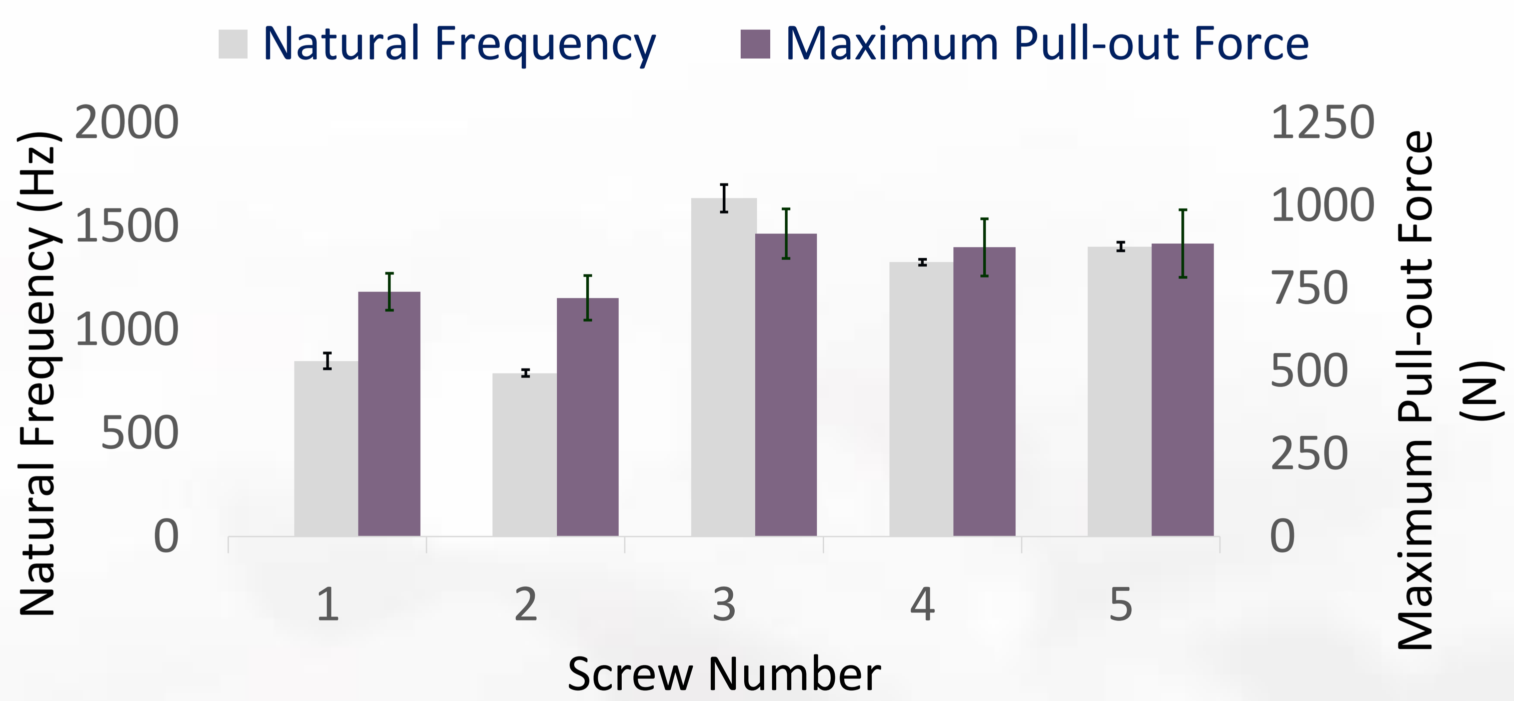

Figure 4: Natural frequency and maximum pull-out force versus every screw number based on the table 1

References

1. Ovesy, M. et al. J MECH BEHAV BIOMED, 1(98), 301-310, 2019.
2. Leuridan, S., Goossens, Q., et al., . J MECH BEHAV BIOMED, 66, pp.12-18, 2017.
3. Standard AJP, USA: ASTM INTERNATIONAL, (2017) F543-17.
4. Kim, Y.Y., Choi, W.S., et al. Spine Journal, 12(2), pp.164-168, 2012.
5. Ketata, H., Affes, F., et al., Biomedical Engineering/Biomedizinische Technik. 2019.

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