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New experimental protocol for dental ceramic wear simulation: Concept proof of a bio-inspired fake mouth design

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1. Introduction

Our knowledges on the different causes of tooth wear are still incomplete. Several in vitro and in vivo studies allow us to understand the influence of various parameters on tooth wear [Bartlett et al. 2013]. Despite this, few experimental protocols include all these parameters in the characterization of the abrasivity of dental ceramics. Our objective is therefore to be in line with the protocols described by [Lambrechts et al. 2006] and add new clinical constraints to it, to get closer to the in vivo conditions of a buccal environment. Through this experimental simulation of the buccal environment, we plan to obtain a better correlation between in vitro and in vivo tests than that obtained by [Heintze et al. 2012] for example.

We propose to design an artificial buccal environment which reproduce the chewing effort coupled to thermo-chemical solicitation. This will allow us to propose a new experimental protocol.

2. Strategy and hypothesis

To design a bio-inspired fake mouth, the biggest challenge was to reproduce the oral environment and the chewing as faithfully as possible. Our strategy was to mimic the mouth and identify the most critical situation encountered. Three constraints to be traduced into technology were identified: chewing, temperature variation and saliva bolus (Table 1).

Anatomic Condition	Strategy
Chewing	Only gliding phase is considered: worst case scenario [DeLong 2006] ⇒ Sliding movement
Saliva bolus	Housing + Hydraulic system to ensure the control of the pH and temperature
Temperature variation	

Table 1 Strategies for the fake mouth design.

3. Bio-inspired design

3.1 Technical solution

The bio-inspired fake mouth is composed by two main part: mechanical and hydraulic.

Mechanical part allows miming the gliding phase by a connecting rod mechanism. It allows harmonic sliding movement of the ceramic sample (flat or teeth profile)

at fixed frequency. The chewing forces where applied by a deadweight. This solution ensures permanent contact between the antagonist and the ceramic sample at the right chosen force and thus leads to wear (Figure 1).

The hydraulic system is composed by two tanks, pumps and valves. The tanks ensure the control of pH and temperature of the chosen solution (water, artificial saliva [Bullon et al. 2015]). The hydraulic circuits (pumps and valves) permits to control that antagonist and sample stay always emerged in the controlled environment.

The mechanical and hydraulic system are commanded through an Arduino control card.



Figure 1 bio-inspired fake mouth: proposed solution

3.2 Experimental protocol

Before starting the tests, it is necessary to define the fluids (type, pH and temperature), chewing force and the number of gliding cycles. With this Bio-inspired fake mouth we can simulate both bruxism (gliding without thermal variations of the fluid) and a case of nutrition that contains hot and cold foods (gliding without thermal variations of the fluid). The experimental protocol is summarized in the following.

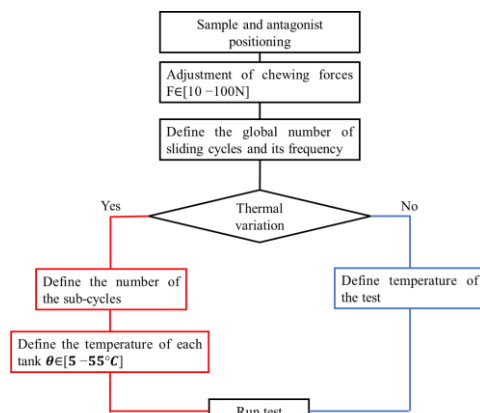


Figure 2 Experimental protocol for wear simulation

At the end of the test, the liquid used is recovered. This liquid is then boiled to evaporate the water. The residue obtained is first analyzed at the SEM instrumented with an EDX probe. The EDX analysis makes it possible to check the nature of the fragments to distinguish their origins (sample or machine). The SEM observation allows to determine their size. AFM analysis is then carried out to determine nanometric fragments. These analyzes offer the possibility of comparing the sizes of fragments generated by mastication in relation to the intestinal barrier.

3.3 Expected results

Through this bio-inspired fake mouth and the proposed protocol we will be able to compare ceramics used for dental prosthesis. This comparison will be based on two main criteria. The first one is the analysis of the lost volume due to wearing. It allows to compare the wearing resistance between ceramics. The second criterion consists on analyzing of the fragment size generating during the wearing simulation. It permits us to verify that these fragments do not exceed the intestinal barrier.

These results combined to mechanical characterization of ceramics allow us to predict the lifetime duration of a ceramic dental prosthesis.

4. Conclusions

The bio-inspired fake mouth allows miming both bruxism and a case of nutrition through

thermomechanical cycling. It permits to give to the dentist some objective criteria for comparison between ceramics and helps them to choose the best one for each patient.

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