Prosthodontic crown mechanical integrity study using Speckle Interferometry

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1 Introduction

New trends in dental prosthodontic interventions tend to reach biomimetic behaviour. Evolutions of CAD-CAM techniques enable to build ceramic prosthetic crowns and, above all, to set the cement joint thickness that links crown and remaining dental tissues. CAD is based on "in-mouth" optical print (i.e. shape on which the clone is glued and contact surface of the opposite jaw tooth). Prosthetic crown is then manufactured, using these parameters, from a feldspathic ceramic rod. In this study, the cloning process gives two samples with identical shape for further use: clone and tooth displacements are measured by speckle interferometry.

2 Design and goals

Several theories [1] discuss the glue thickness and its formulation, acting as a crucial interface that accomodates the different stresses applied to the prosthetic tooth. Moreover this biomechanical analysis tries to reproduce the natural behaviour of the dentine-enamel joint (DEJ). In order to validate these new concepts and materials, and to study the mechanical properties and the mechanical integrity of the prosthesis, high resolution optical measurements of the deformations of glue and crown are required [2]. In our case, samples are two intact premolars extracted for orthodontic reasons from the same patient. The reference sample is preserved while the second sample tooth is shaped to receive a feldspathic ceramic monoblock crown (clone of the reference). Vertical cuttings have also been used to allow planar object observation, and also to appreciate the differential

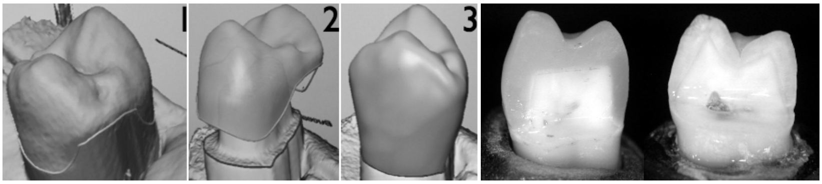

Fig. 1. Cloning process (1 ref optical print, 2 shaping, 3 CAM ready), clone and master cuts

behaviours "inside" the tooth: the crown-glue-dentine joint for the clone and the DEJ for natural tooth (Fig.1). For this study, a tooth compression test device and an optical fibers in-plane sensitive speckle interferometer have been developed. Samples are white powdered to diffuse laser light.

2.1 Mechanical set-up

The mechanical set-up is presented in Fig.2. Our compression test device fulfills the high sensitivity of speckle interferometry and also copes with the rigid body motions of the whole system. The sample tooth is placed in a dedicated mold in the lower jaw while the force transducer holder is slowly translated vertically by the stepping motor. The system can generate a „force-driven" displacement, or just a „user" displacement. The whole mechanical system is screwed on the holographic table top.

The force can be applied to the tooth directly with the force transducer or using a relay rod (shorter than shown Fig.2). We can point out that the force is always applied on the same part of the tooth surface for all the samples. This requires some degrees of adjustment to place the lower jaw properly. Samples have got molded jaw or have just been cemented.

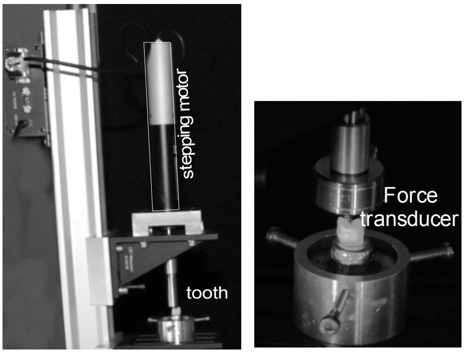

Fig. 2. Compression test mechanical set-up and dedicated molded lower jaw

2.2 Optical set-up

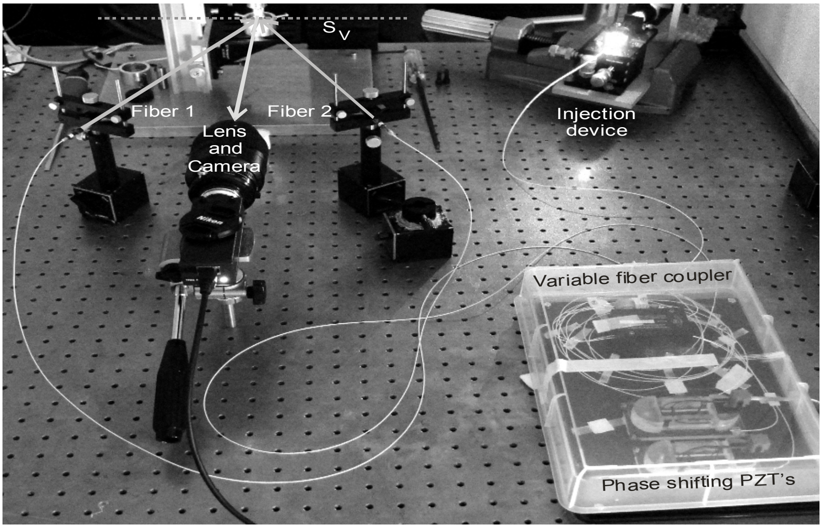

Fig. 3. In plane speckle interferometer, showing observation and illumination beams (full), sensitivity vector S_V (dashed), variable coupler, phase shifting and injection devices.

The optical set-up is presented in Fig.3. This COTS system (Canadian Instruments) offers injection, variable intensity coupling in the output fibers and also phase shifting. Parts of the output fibers are bared and wrapped around piezoelectric transducers. The phase shift is applied on any or both of the two output fibers. The system is protected from thermal and mechanical effects by a plastic box and is easily breadboardable. Phase shifts have been calibrated using common procedures [3].

Because in-plane displacements are of great interest for orthodontic measurements, an optical fibers in-plane sensitive interferometer has been designed. Horizontal sensitivity is achieved. A “4-buckets” phase shifting algorithm [4] leads to phase variations during the compression test.

3 Results and conclusion

First results have been obtained for different loads (Fig.4). In-plane displacement fields from speckle interferometry already showed interesting data concerning the mechanical behaviour of the different tooth parts. The particular behaviour of the interface joining them histologically is very important for dental aspects.

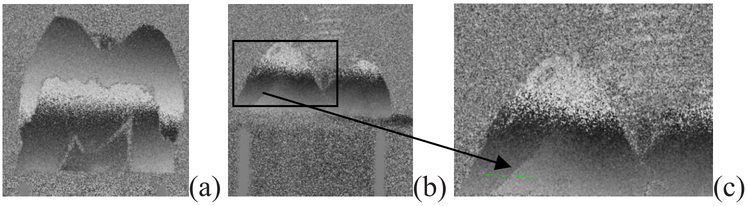

Fig. 4. Clone (a) and natural tooth (b) in-plane displacements, and (c) DEJ detection zoom

The loading range applied to the different samples are between 5 N and 120 N. Clone crown and natural tooth showed differential displacements: about 60nm for DEJ and about 100nm for the glue joint at the applied loads (20N and 40N). Each sample behaves as single solid beyond 120N.

These measurements show that the natural enamel crown moves independently from dentine. This difference is clearly delimited by a line corresponding to the anatomical location of the dentine-enamel junction (DEJ). For the ceramic clone the same kind of shift occurs at the glue junction of the ceramic crown with the dentine [5].

In further processing, optical displacements will be compared to finite elements analyses of the tooth. Mechanical sensitivity of the tooth surrounding medium will also be examinated.

4 References

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