Biomechanical behaviour of the periodontal ligament in initial tooth movement

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Introduction

Most classical studies consider the PDL as an isotropic and linear elastic material. More recently, increasing evidence is reported that it behaves as an anisotropic material in which collagen fibres play an important role. Up to now, only limited data are available that describe the *in vivo* behaviour of the PDL after controlled transitional force application. It is still a challenge to collect reliable data to characterize the structural complexity of the PDL.

The purpose of this study was to provide experimental data that can be used in that approach. Since the mechanical behaviour of the PDL is time dependent, we studied the response of the periodontal ligament during the first five hours of application of different orthodontic forces in an experimental model in beagle dogs. We hypothesise that the PDL can be described as a poroviscoelastic fibre-reinforced material.

Material and Methods

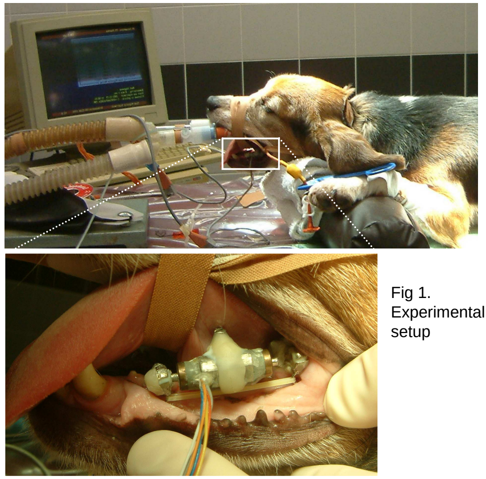

Fig 1. Experimental setup

Seven young adult male beagle dogs (age 1.0 – 1.5 years) were used in the experiment.

After extractions and placement of implants, custom made orthodontic appliances were placed on both sides of the mandible. The appliance was designed to allow only bodily movement of the second premolars to the distal.

The displacement transducer was fixed to the implant and a magnetic bar was fixed to the second premolar so that it slid with minimum friction through the transducer.

Tooth movement was measured during the first 5 hours of force application. Each dog had 2 measurement sessions. One premolar was moved with a force of 100 cN in the first session and with 50 cN in the second, while the contralateral premolar was moved with 100 cN and 300 cN respectively.

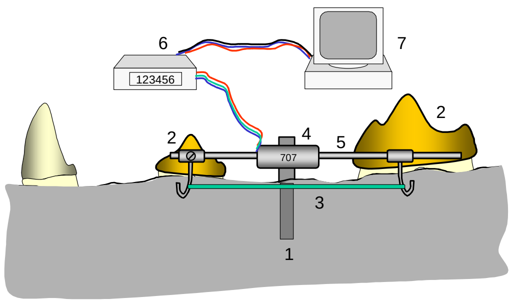

Fig. 2. Schematic drawing of experimental appliance and measuring system. 1) implant, 2) crowns, 3) elastic, 4) displacement transducer, 5) magnetic ruler, 6) digital counter, 7) PC.

Results

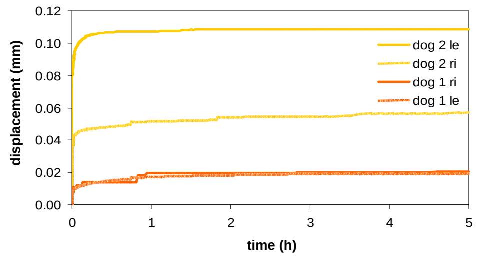

Fig. 3. Tooth displacement curves of 2 dogs with a force of 100 cN (le = left side, ri = right side).

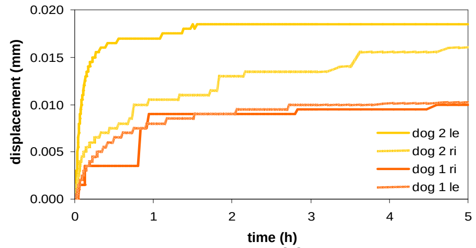

Fig. 4.Tooth displacement curves of the same dogs as in Fig. 3 after resetting the displacement after the first minute of force application.

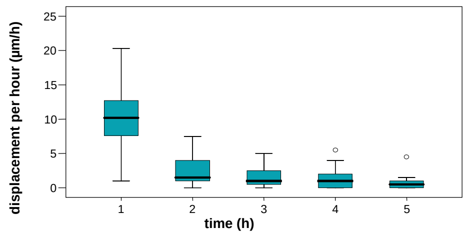

Fig. 5. Boxplot of displacement per hour for all measurements with100 cN force.

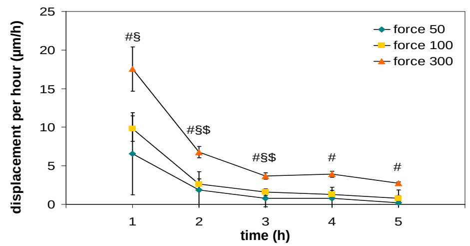

Fig 6. Means ± SEM of the displacements per hour in µm/h for the periods for the different forces.

All time displacement curves showed the same general outline. There was a first phase that lasted for only a few seconds in which an instantaneous rapid tooth movement was found. During the rest of the experimental period a gradual creep movement was found and a plateau was reached after approximately five hours.

A large individual variation was seen between dogs and even within dogs (Fig. 3). However, resetting the displacement after one minute showed that the difference largely originated from the first minute.(Fig. 4).

The displacement per hour decreased with time and also the individual variance became less (Fig. 5).

Besides a difference between dogs also an effect of force magnitude on the displacement per hour was found (Fig. 6). At earlier time points the higher forces resulted in significantly larger displacement. However, this difference was only significant up to the first 3 hours.

Conclusion

The time-displacement curve showed a rapid initial response followed by a gradually decreasing creep. The first part of the curve can be explained by a fast exudation of fluid and unrolling of slack fibres. The second part can be explained by stretching of fibres.

A material model that describes both phenomena should therefore consist of both a fibre component and a porous component that allows fluid flow. Therefore, this study supports our hypothesis that the PDL behaves as a poroviscoelastic fibre-reinforced material.