A Force on the Crown and Tug of War in the Periodontal Complex

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Appendix

Limitations and Future Work: 1. Results in this review are limited to relationship between tooth-bone biomechanics and local mechanobiological events within a dentoalveolar complex loaded under physiological conditions, and that these results should be revisited in the context of biomechanics of the entire oral and craniofacial masticatory complex. **2.** A limitation of imaging *in situ* using an intact dentoalveolar fibrous joint is that it does not account for hydrostatic pressures (Herring 2012). However, *ex vivo* modeling is able to distinguish differences between joints adapted to various types of prolonged functional loads (Jang et al. 2015). Furthermore, once fabricated, biosensors can aid in providing bite forces in *in vivo* models and when paired with *in situ* experiments will provide accurate information on the travel of forces from the tooth-crown into the periodontal complex. **3.** Modeling *in situ* can be improved through interdigitation of maxillary and mandibular teeth within the integrated masticatory complex (Fig. 2) for an accurate representation of the tooth-bone association. **4.** Increased signal to noise ratio of acquired X-ray tomograms of the PDL-space between mineralized bone and tooth related tissues would enable an accurate representation of the size of the tether between cementum and alveolar bone, and thereby modeling of the periodontal complex. **5.** Colocalization of molecules and clusters of molecules within intact specimens that contain mineralized tissues in 3D-space must be performed. Therefore, correlative microscopy approach will enable accurate extraction of the mechanistic link between joint-level biomechanics to site-specific tissue-level mechanobiological processes.

Appendix Table 1. Previous works by others related to load-mediated adaptation of the dentoalveolar complex and respective outcomes mostly in rats

Author	Loading Regime	Methods	Outcome measures to identify adaptations	Year
(Tomes 1882)	as per habitat	species specific (a variety of mammals)/environment based foods	morphology of tooth, jaw and muscles	1882
(Hiiemae 1967)	physiologic	consistencies – various food types given to rats (electromyograms, radiographs)	altered form and function of the masticatory system	1967
(Bondevik 1980)	therapeutic (intrusive forces)	orthodontic appliance in rats (histology, radiography)	narrowing of PDL-space, cell free zones - recovery after 1-2 weeks	1980
(Thomas and Peyton 1983)	physiologic	soft diet – pudding given to rats (electromyography)	decreased bite force,	1983
(Kiliaridis et al. 1985)	physiologic	soft diet - food mixed with water given to rats (electromyography)	skull became more orthocranial in shape - no change in skull volume - decrease growth rate of angle mandible	1985
(King et al. 1991)	therapeutic	springs placed in rats (radiography, and histomorphometry)	dental drift complementary to loads	1991
(Alhashimi et al. 2000)	therapeutic	ortho spring in rats (histomorphometry, immunohistochemistry)	change in expression of IL-1β, IL-6, TNF-α	2000
(Ren et al. 2003)	therapeutic	orthodontic spring in rats (radiography)	age-related tooth movement	2003
(Mavropoulos et al. 2004b)	pathologic	porridge (bite block) in rats (radiography)	altered bone volume density	2004
(Mavropoulos et al. 2004a)	pathologic	bite block in rats (radiography)	shifts in mandibular growth	2004

Author	Loading Regime	Methods	Adaptations	Year
(Enokida et al. 2005)	pathologic	hypofunction - recovery (bite plates on incisors) in rats	change in histomorphometry and RANKL distribution	2005
(Wada et al. 2008)	pathologic	Hypofunction in rats	elastic property and bone formation (fluorochrome)	2008
(Kingsmill et al. 2010)	physiologic	soft diet - powered chow as paste given to rats	decreased bone volume, mineral density, alcian blue staining (GAG)	2010
(Niver et al. 2011)	physiologic	soft diet – powder diet given to rats	decreased attenuation lines (μ-XCT) , decreased hardness (microindentation)	2011
(Jiang et al. 2017)	physiologic	soft/powdery diet and hard diet given to rats	role of vascular endothelial growth factor expression in temporomandibular joint development and remodeling in response to functional loading	2017

Appendix Table 2. Previous works by others related to experimental mechanics to map strains within tissues of teeth, periodontal complex and their interfaces

Author	Method	Outcome measure	Year
Wang and Weiner 1998	Moiré Interferometry on human tooth structures	Strain maps as related to human tooth structures	1998
Asundi and Kishen 2000	Strain gages and photoelastic materials simulating premolars	Mechanical strains within the simulated interfaces, and teeth	2000
Jantarat et al., 2001	Mechanical testing on extracted human maxillary premolars	Tooth deformation as related to percent moisture	2001
Wood et al., 2003	Moiré Interferometry on human teeth	Cuspal displacement and subsequent recovery – time and load-dependent properties using human teeth	2003
Popowics et al., 2004	Mechanical testing on porcine mandibular molars	Load-displacement curves as related to biomechanics of the molar periodontal complex	2004
Zaslansky et al., 2005	Speckle interferometry on human dentin	Mechanical strain and Young's modulus of human dentin	2005
Qian et al., 2009	Digital image correlation and finite element methods on porcine dentoalveolar complex	Time dependent viscoelastic behavior of the tooth, the periodontal ligament and interfaces	2009
Zhang et al., 2009	Digital image correlation of human teeth	Strain maps as a result of percent moisture in dentin and enamel	2009
Naveh et al., 2012	*In situ* loading device coupled to an X-ray computed tomography unit on porcine/rat dentoalveolar complexes	Visualization of tooth translation relative to bone	2012

Lin et al., 2013	*In situ* loading device coupled to an X-ray computed tomography unit and digital image correlation to generate deformation maps in human and rat dentoalveolar complexes	Visualization of function: displacements of tooth in three-dimensional space relative to alveolar socket	2013
Jang et al., 2015	*In situ* loading device coupled to an X-ray computed tomography unit and digital volume correlation to generate deformation maps on rat dentoalveolar complex	Visualization of function: deformations within the periodontal spaces – narrowed and widened spaces resulting from experimental tooth movement and/or loading on the tooth-crown	2015

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