UNIVERSITY HOSPITAL

Department of Operative Dentistry and Periodontology

Chair of Dental, Oral, and Maxillofacial Medicine – especially Operative Dentistry, Periodontology, and Pediatric Dentistry

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Research focus
- Clinical fractography on dental ceramic restorations
- Characterization of lithium silicate glass-ceramics
- Evaluation of new translucent zirconia
- Tailored mechanical test procedures to predict clinical failure mechanisms
- Amalgam alternative restoration materials
- Hydrolysis and fatigue of modern CAD/CAM restoration materials
- Novel materials and techniques for adhesive luting of glass-ceramic restorations
- Wear behavior of dental restoratives against zirconia

Structure of the Department

Professorship: 1
Personnel: 55
- Doctors (of Medicine): 22
- Scientists: 3
- Graduate students: 30

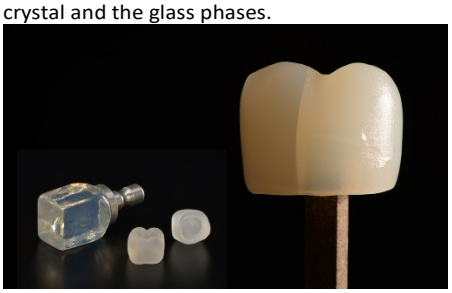
Clinical focus areas
- Operative Dentistry
- Endodontic treatment
- Systematic periodontal treatment
- Pediatric dentistry

Research

The main focus is on dental materials research with fields of expertise in basic science of operative and endodontic treatment procedures and correlation of experimental findings with clinical outcome. Independent, pre-clinical assessment and material development is a further area of interest of the research laboratory.

Clinical fractography on dental ceramic restorations
PI: R. Belli, U. Lohbauer
After the commercial launch of new dental ceramic materials, an increased incidence of intra- oral fractures or chippings has been observed. The method of fractography is intended to clinically analyze failed dental restorations in order to identify relevant fracture mechanisms. In principle, fracture surfaces are intraorally replicated and macroscopically or microscopically investigated, using light or scanning electron microscopy. Specific fracture patterns thus provide information of involved failure mechanisms and respective reasons for failure. In a joint project with a German CAD/CAM milling center, approximately 1,000 failed restorations were fractographically examined and relevant reasons for failure were assessed. Based on the results originating from the Department of Operative Dentistry and Periodontology, a new nonprofit organization (Fracto Forum International e.V.) was founded. An international hands-on workshop on dental fractography was organized in 2019 in Erlangen with support from the Institutes of Pathology (Prof. Hartmann) and Palaeontology (Prof. Munnecke).

Characterization of Lithium Silicate glass-ceramics
PI: R. Belli, U. Lohbauer
Restoratives based on Lithium Silicate glass-ceramics are relatively new, but a popular dental material. However, some intrinsic problems of these systems have been recognized both in the laboratory and clinic, namely, the susceptibility to thermal shock cracks and incompatibilities between the crystal and the glass phases.

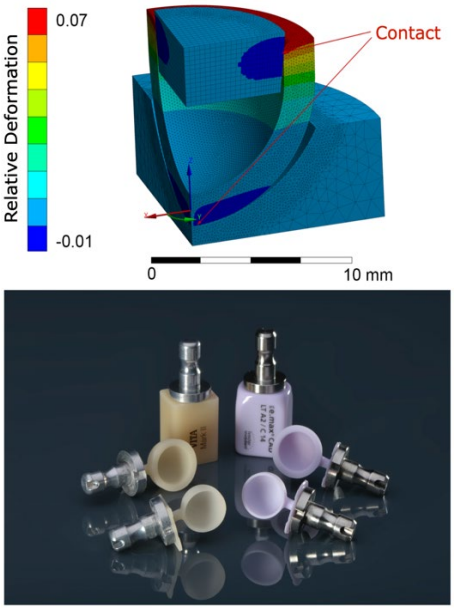


Spontaneously fractured dental crown due to thermal incompatibilities in the ceramic.

We investigate these phenomena in collaboration with the Department of Materials Science (Prof. deLigny) by studying the kinetics of nucleation and crystallization of commercial and experimentally synthesized formulations, especially the effect of zirconia addition, in order to gain insight into the thermal and mechanical behavior of these system, to ultimately improve their clinical performance.

Evaluation of new translucent zirconia materials
PI: R. Belli, U. Lohbauer
Modern zirconia dental restoratives have expanded their clinical indication towards improved optical properties. The compositional modifications in zirconia induce changes in the microstructure thereby reducing their mechanical properties significantly. We took these new zirconia materials under scrutiny by investigating their crystallographic polymorphs in collaboration with the Institute of Applied Mineralogy (Prof. Götz-Neunhoeffer). High-precision mechanical testing aided in establishing reliable structure-property relationships.

Tailored mechanical test procedures to predict clinical failure mechanisms
PI: R. Belli, U. Lohbauer
Our experience with fractographic evaluation of clinically fractured prosthetic components has shed light on the most common types of failure that happen during service in the oral environment. In order to fully comprehend the mechanical aspects of such failures, it is necessary to transfer the geometric and loading conditions to an experimental set-up. We developed model geometries such as that of dental crowns, digitally produced and machined them out of commercially available materials, and subjected this experimental setting to simulate the stress distribution in the mouth. In collaboration with the Department of Engineering Design (Prof. Wartzack) we reinforced our tests with computer simulations using the Finite Element method, which help identifying locations of stress concentrations that are used for the validation of the fracture test.



Simulation (above) of a model sphero-cylindrical model crown geometry, with ceramic test specimens (below).

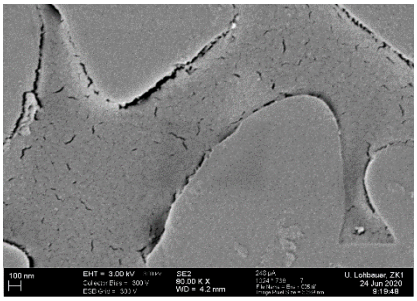
Amalgam alternative restoration materials
PI: R. Belli, U. Lohbauer
Amalgam has been used in the past for treatment of small, carious defects in a wide, permanent, and insurance-covered manner. Adhesive polymer based materials are not sufficiently economical, while glass ionomer based materials do not provide sufficient strength potential for permanent supply. In the research laboratory, new materials are being

investigated that meet the requirements of mechanical strength as well as cost-effectiveness without adhesive bonding and without light polymerization.

Hydrolysis and fatigue of modern CAD/CAM restoration materials
PI: R. Belli, U. Lohbauer
The amount of water taken up by an indirect restorative resin composite material is essential for the assessment of resistance against cyclic fatigue loading and dimensional expansion. We investigated the kinetics of water diffusion into polymer networks by employing a new technique – the Karl-Fischer Titration. We aimed to correlate the water uptake with mechanical fatigue degradation by correlating with dimensional changes of the restoration material upon hydrolysis.

Novel materials and techniques for adhesive luting of glass-ceramic restorations
PI: J.I. Zorzin, U. Lohbauer
One of the most important therapies in dentistry is the restoration of tooth structure defects with glass-ceramic restorative materials. The objective of the research work is to investigate novel materials and techniques for the adhesive luting of indirect glass-ceramic restorations - such as self-adhesive luting resins, universal adhesives and self-etching glass-ceramic primers - with regard to their mechanical load-bearing capacity. Investigations on self-adhesive luting resins showed that swelling and expansion stress of these materials are significantly influenced by their pH neutralization. Materials with low pH neutralization resulted in swelling and failure of ceramic restorations by fracture in vitro. For universal adhesives, sufficient adhesion to glass-ceramic restorative materials was only achieved when they were processed like conventional adhesives using hydrofluoric acid and silane. With self-etching glass-ceramic primers, adhesion was sufficient even without additional application of other materials.

Wear behavior of dental restoratives against zirconia
PI: E. Maier, U. Lohbauer



Wear mechanisms on the nanoscale using high-resolution SEM imaging.

The behavior of human enamel, as well as restorative materials, in the oral occlusion is a focus of clinical interest due to an increasing number of patients with stress-related craniomandibular dysfunction. The resistance of nanohybride composites and advanced ceramic materials to these mechanical fatigue stresses can be evaluated in preclinical settings.
Two-body wear - using an artificial chewing simulator in direct occlusal contact - versus three-body wear - employing a millet seed suspension to mimic food comminution – are used to simulate the direct contact of two antagonists. Increasingly popular Zirconia restoratives seem problematic in this aspect due to their diamond-like hardness. Micro-morphological investigations under the scanning electron microscope are used to analyze the causes of differences in abrasion behavior. The aim of our wear investigations is to enable preclinical predictability of the resistance and longevity of different restorative materials and thus to tailor clinical indications.

Teaching

The Department of Operative Dentistry and Periodontology is involved in the curricular teaching within the frame of the dental students' degree program. Interdisciplinary lectures are held at the institute of Biomaterials (Prof. Boccaccini). In 2018, the Department of Operative Dentistry and Periodontology released a comprehensive text book for dental students entitled „Werkstoffkunde in der Zahnmedizin – Moderne Materialien und Technologien". The Department offers supervision of Bachelor's and Master's theses as well as MD and PhD theses in conjunction with the Departments of Medical Technology, Biomaterials, Engineering Design, and Materials Science and Engineering.

Selected publications

Belli R, Zorzin JI, Petschelt A, Lohbauer U, Rocca GT. Crack growth behavior of a biomedical polymer-ceramic interpenetrating scaffolds composite in the subcritical regimen. Eng Fract Mech 2020;231:107014.

Belli R, Völkl H, Csato S, Tremmel S, Wartzack S, Lohbauer U. Development of a hoop-strength test for model sphero-cylindrical dental ceramic crowns: FEA and fractography. J Eur Ceram Soc 2020;40:4753-4764.

Belli R, Loher C, Petschelt A, Cicconi MR, de Ligny D, Anglada M, Lohbauer U. Low-temperature degradation increases the cyclic fatigue resistance of 3Y-TZP in bending. Dent Mater 2020;36:1086-1095.

Tiu J, Belli R, Lohbauer U. Rising R-curves in particulate/fiber-reinforced resin composite layered systems. J Mech Behav Biomed Mater 2020;103:103537.

Kirsten J, Belli R, Wendler M, Petschelt A, Hurle K, Lohbauer U. Crack growth rates in lithium disilicates with bulk (mis)alignment of the $Li_2Si_2O_5$ phase in the [001] direction. J Non-Cryst Solids 2020;532:119877.

Werbach K, Hummel S, Ebner C, Lohbauer U, Peterlik H. Pitfalls of determining the elastic properties of stabilized zirconia with indentation methods. Ceram Int 2019;47(B):9491-9496.

Lohbauer U, Wendler M, Rapp D, Belli R. Fractographic analysis of lithium silicate crown failures during sintering. SAGE Open Medical Reports. 2019;7:1-8.

Wendler M, Belli R, Lohbauer U. Factors influencing the development of residual stresses during crystallization firing in a novel lithium silicate glass-ceramic. Dent Mater 2019;35:871-882.

Maier EB, V.; Belli, R.; Taschner, M.; Petschelt, A.; Lohbauer, U.; Zorzin, J. New approaches in bonding to glass-ceramic: Self-etch glass ceramic primer and universal adhesives. J Adhes Dent. 2019;21:209-217.

Zorzin J, Beck S, Belli R, Petschelt A, Boccaccini AR, Lohbauer U. Adhesion and interfacial characterization of biomimetically texturized lithium disilicate. Int J Adhes Adhes. 2019;91:131-41.

International cooperations
Prof. H. Peterlik, Institut für Physik, Universität Wien, Vienna: Austria

Prof. T. Lube, Institut für Struktur- und Funktionskeramik, Montan Universität Leoben, Leoben: Austria

Prof. S. Scherrer, University of Geneva, Geneva: Switzerland

Prof. Y. Zhang, Penn State University, Pennsylvania, USA

Prof. J. Ferracane, Oregon Health & Science University, Portland, USA