Zirconia-reinforced dental restorations
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CHAPTER 6

Summary and Conclusions
All-ceramic restorations have, mainly due to their excellent optical properties, an increasing interest in dentistry. In the past, this type of restorations were made from materials that did not match the strength of the natural materials that had to be replaced, requiring drastic tooth preparation to enable the restorations being strong enough. A few years ago, a new core material, yttrium tetragonal zirconia polycrystals (Y-TZP), was introduced in dentistry for the creation of all-ceramic restorations. This material is strong and does not require extensive tooth preparation. However, due to its opaque white color the aesthetic properties are not as good. A veneer layer of aesthetic porcelain has to be used to optimize the color of the restoration. The superior mechanical properties of zirconia combined with the art of CAD/CAM fabrication procedure allowed fabrication of large and complex restorations, such as fixed dental prosthesis (FDP), with high accuracy and success rate. This thesis has been performed to improve the knowledge of how can zirconia be used to reinforce the FDPs.

Chapter 1, the general introduction of this thesis, presents an overview of the fabrication history of FDPs, from the traditional way to the CAD/CAM technique. Failure mechanism such as debonding and fracture, are briefly explained. Finally, the aim and the outline of this thesis are described.

In chapter 2, the influence of sintering procedure on the intrinsic properties of zirconia was investigated. Zirconia discs were sintered at the final temperature of either 1200°C or 1350°C for different times. The density, biaxial flexural strength (BFS), and grain size of all the sintered zirconia were measured. The densities and BFS of zirconia discs sintered at the final temperature of 1350°C were not influenced by the sintering procedure. However, for the zirconia discs sintered at a lower final temperature of 1200°C, the densities and BFS generally increased, to some extent, with the holding time. The zirconia disc sintered at a relatively low temperature of 1200°C were more likely to obtain a smaller grain size, while the grain size increased with the holding time. It was also shown that there was a linear relation for the factors density, BFS, and grain size.

A novel experimental coating was introduced in Chapter 3. The aim of the research described in this chapter was to improve the bond strength of zirconia with resin cement. For this experimental coating method a thin layer of flowable composite, which contains zirconia-silica nanoparticles, was spread on a fully sintered zirconia discs and then sintered at 1200°C for 10 min. During sintering, the resin matrix burned away, leaving the filler particles on the zirconia surface, which could fuse to the zirconia surface and resulting in a zirconia-silica coating layer. The coated and uncoated zirconia discs were further cemented to resin composite substrates by applying
three different priming conditions: no primer, a MDP-containing primer or a silane coupling primer. The bi-layered specimens were cut into microbars and stored in water either for 24 hours or 30 days, before their micro tensile bond strength (MTBS) was evaluated. Scanning electronic microscope (SEM) observation was used to judge the fractures. The coated zirconia combined the treatment of silane coupling primer showed the highest MTBS after 24 hours in water. Water storage time largely affected the MTBS of the un-coated zirconia, while only partially for coated the zirconia. SEM analysis revealed a failure mode change after water storage for the un-coated zirconia, from a mainly cohesive or mixed mode into an adhesive one. However, the fracture mode was always mixed or cohesive for the coated zirconia.

The possibility of using resin composite to replace the conventional FDP materials was studied in Chapter 4. Conventional permanent FDPs, including metal-ceramic FDPs and zirconia based all-ceramic FDPs, were compared to 3 types of resin composite FDPs: plain resin composite, fiber-reinforced resin composite (FRC), and zirconia-bar-reinforced resin composite (ZRC). The average load-bearing capacity for FRC FDPs and ZRC ones were significantly higher than the average of the other three groups. The mean work to fracture (W_f) of FRC FDPs was significantly higher than the other four groups. The FEA results showed that the bottom of the connectors was the weakest part of the three resin composite FDPs. It showed that the resin composite FDPs can be considered as an alternative to conventional FDPs, especially when they are reinforced either by fibers or zirconia bars, with the limitation that the fatigue properties were not investigated, yet.

In chapter 5, a newly zirconia reinforced CAD/CAM resin composite (Lava Ultimate CAD/CAM) was compared with an industrially fabricated ceramic (IPS e.max CAD ceramic). The onlay type restoration of different thicknesses were made and subjected to a fracture resistance test. The stress distribution for 0.5 mm restorative discs was analyzed by Finite Element Analysis (FEA). For the same thickness of testing discs, the fracture resistance of polished Lava Ultimate discs was always significantly lower than the sandblasted ones or the IPS e.max ones. However, the lowest load fracture value was still clinical acceptable. There was a linear relation between fracture resistance and restoration thickness for the polished Lava discs and for the sandblasted IPS e.max ones. FEA showed a compressive permanent surface deformation in all the analyzed discs. Based on the fracture resistance and FEA results, it could be concluded that restorations with thicknesses above 0.5 mm can be clinically used for both materials. However, Lava Ultimate CAD/CAM material is recommended...
if ultrathin restorations are required. When this material is used, the surface treatment of sandblasting is suggested.

The series of studies conducted in this thesis showed that there are several ways to enhance the performance of fixed restorations regarding the application of zirconia. One possible way is to change the sintering procedure of zirconia, so that the physical properties of zirconia such BFS, density or grain size can also be changed. In the other hand, with the experimental zirconia-silica coating technique, the bond strength of zirconia frameworks can be improved, in order to reduce the clinic failure rate caused by debonding. Besides the improvement of zirconia itself, it can be also used to reinforce other materials as a substitute to the brittle veneering porcelains. Furthermore, the zirconia nanoparticles can be used as fillers for both traditionally or industrially fabricated resin composite, whose in vitro performance is still quite good. With the increased bond strength of zirconia and resin composite, the composite veneered zirconia framed fixed restorations can be studied in the future.