Effect of sinter time on fatigue reliability of monolithic full anatomic Y-TZP crowns

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Objective:

To evaluate the effect of sinter time on thermo-mechanical fatigue behaviour and in-vitro longevity of monolithic full anatomic Y-TZP crowns.

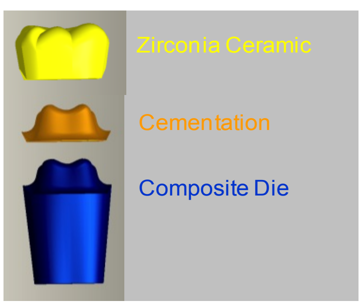
Null Hypothesis: There is no difference in fatigue behaviour and reliability of monolithic full anatomic Y-TZP crowns with modified sinter times compared to the standard sinter time (Control group: Tested in a previous study under identical conditions).

Materials & Methods:

Crown/ Sample preparation:

Monolithic full anatomic Y-TZP crown specimens were cemented to dentin-like based composite dies.

Figure 1: Crown specimen structure



1. **Composite dies** (Tetric Evo Ceram, Ivoclar Vivadent, Liechtenstein), used as a substrate to simulate dentin of a natural tooth. (Dies were produced in **Freiburg**)
2. **Luting cement** (Multilink Automix adhesive cement), used to cement the substrate to the restoration (Crowns were cemented in **Freiburg**)
3. **Zirconia ceramic** (InCoris TZI Crowns were milled by **Sirona**)

A master die (standard crown-preparation of a mandibular molar) set up in a mandibular dentoform model with opposing maxillary dentition were provided. The full anatomic crown design given by the CAD/CAM system (Cerec MCXL, Sirona, Germany) was used for the Y-TZP crown fabrication. CAD/CAM milled zirconia ceramic (InCoris TZI, Sirona) crown samples were supplied by Sirona. The experimental groups were comprised of:

Test Group Zirconia Super Speed Sinter Time (n=28) – Monolithic, full anatomic Y-TZP zirconia ceramic (InCoris TZI, Sirona) with speed sinter time (10 min)

Test Group Zirconia Speed Sinter Time (n=28) – Monolithic, full anatomic Y-TZP zirconia ceramic (InCoris TZI, Sirona) with speed sinter time (1h)

Test Group Zirconia Long-term Sinter Time (n=28) – Monolithic, full anatomic Y-TZP zirconia ceramic (InCoris TZI, Sirona) with long-term sinter time (7h)

Control Group Zirconia Standard Sinter Time (n=28/ already tested) – Monolithic, full anatomic Y-TZP zirconia ceramic (InCoris TZI, Sirona) with standard sinter time.

The number of specimens for each group was based on statistical power analysis.

Figure 2: Monolithic full anatomic Y-TZP InCoris TZI crowns, a) Super Speed, b) Speed, c) Long-term sintered

Resin-based composite (RBC) dies (Tetric Evo Ceram, Ivoclar Vivadent, Liechtenstein) were prepared and light cured in a standard manner. Dies were stored in water for a minimum of 21 days prior to cementation. The cementation procedure with Multilink Automix followed manufacturer's recommendation. Prior to testing, cemented crown specimens were incubated in water at 37 degrees C° for at least 7 days.

***Fatigue Analysis**:*

Samples (n= 14) were exposed to mouth-motion fatigue using a chewing simulator (Willytec, Germany) with load application of 198 N for 1.2 Mio cycles at a frequency of 1.6 Hz. Mechanical testing was performed by sliding a steatite indenter (Hoechst Ceram Tec, Germany r= 3 mm) 0.5 mm down the mesio-lingual cusp towards the central fossa. Simultaneously all samples were exposed to thermal cycling at 5 to 55 degrees at intervals of 60 seconds. During cyclic loading, crowns were inspected for crack and/or fracture failures. After cyclic loading a binocular microscope (Olympus SZH 10, Germany) was used to detect failures.

Crowns with bulk or cohesive fracture were considered as failures.

Load to failure:

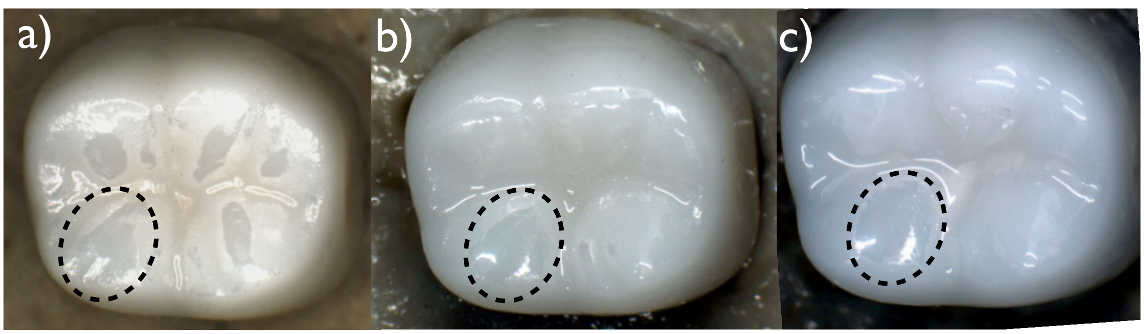
Load to failure Hertzian contact testing was performed using a universal mechanical testing machine (Zwick, Germany). Samples were tested before (n=14) and after (n=14) mouth-motion fatigue. Load was applied through a steel ball (r= 3.18 mm) at a crosshead speed of 1.5mm/min until fracture of the ceramic material occurred. The mean value was determined.

Results:

Fatigue Exposure

All tested monolithic Y-TZP crowns showed no bulk or cohesive fracture failures during and after mouth-motion fatigue. The 5-year simulated survival rate of monolithic Y-TZP crowns at 200 N was 100%. Only superficial wear of the glazing material was observed. The glossy surface of the Y-TZP ceramic in the area where the 200 N sliding load was applied over 1.2 mio cycles, is depicted in Figure 3.

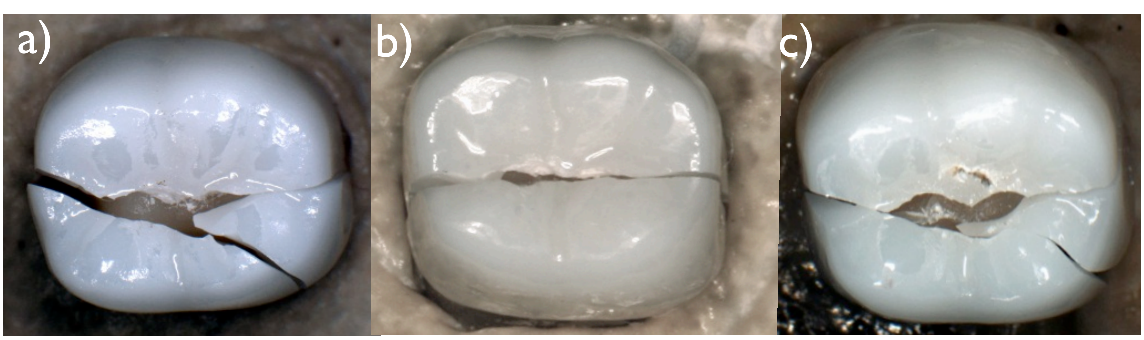
Figure 3: Monolithic Y-TZP crowns after fatigue, circle indicates load application area a) Super Speed, b) Speed, c) Long-term sintered.



Load to failure

Single load to failure testing resulted in ceramic bulk fractures within the restoration material of monolithic Y-TZP crowns.

Figure 4: Y-TZP bulk fracture after single load to failure test after mouth-motion fatigue; a) Super Speed, b) Speed, c) Long-term sintered.

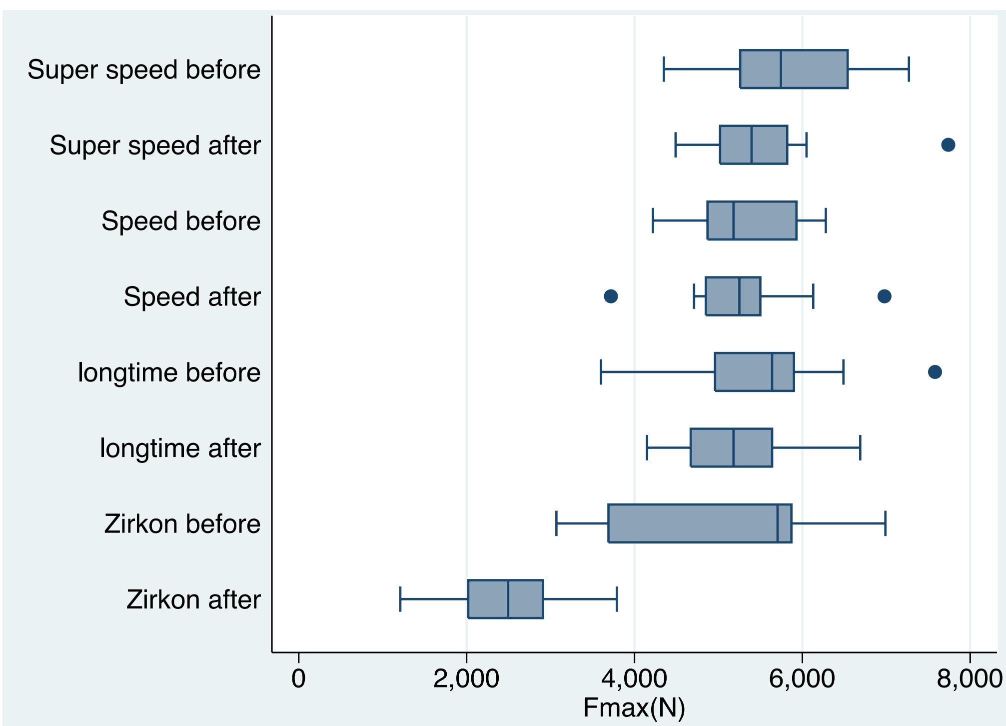


Mean failure loads of monolithic Y-TZP crowns with different sinter times before and after mouth-motion fatigue are displayed in Table 4.

Table 4: Single load to failure results (N) of monolithic Y-TZP crowns before and after mouth-motion fatigue

	Mean	Standard Deviation	Min	Max	25%	75%
Super speed before fatigue	5844	886	4350	7270	5260	6540
Super speed after fatigue	5466	814	4490	7740	5020	5820
Speed before fatigue	5324	668	4220	6280	4870	5930
Speed after fatigue	5274	740	3720	6980	4850	5500
Long-term before fatigue	5536	983	3600	7580	4960	5900
Long-term after fatigue	5220	742	4150	6990	4670	5640
Zircon before fatigue (Control group)	5141	1194	3070	6990	3690	5870
Zircon after fatigue (Control group)	2531	682	1210	3790	2020	2910

Figure 5: Box plots of the load to failure test results in newtons (N).



Statistical analysis

Statistics for group and level comparisons are presented in Table 5 and 6. All p values were adjusted according to the Scheffe Method; family-wise level of significance, 0.05.

No significant difference between all groups could be found before fatigue (Table 5). After fatigue the control group Zirkon revealed a significantly lower facture load than the Speed, Super Speed and Long-term sintered group (Table 5). All significant comparisons are highlighted in bold.

Table 5: Results of fracture load comparisons between groups at the same level

Comparison	Adj. p-value
Super speed before vs. Speed before	0.918
Super speed before vs. Long-term sintered before	0.996
Super speed before vs. Zirkon before	0.692
Super speed after vs. Speed after	1.000
Super speed after vs. Long-term sintered after	0.999
Super speed after vs. Zirkon after	**0.000**
Speed before vs. long-term sintered before	1.000
Speed before vs. Zirkon before	1.000
Speed after vs. Long-term after	1.000
Speed after vs. Zirkon after	**0.000**
Long-term sintered before vs. Zirkon before	0.982
Long-term sintered after vs. Zirkon after	**0.000**

Fatigue had no significant effect on the test groups Speed, Super Speed and Long-term sintered. A significant decrease of fractures load values was observed with the Zirkon control group (Table 6).

Table 6: Results of fracture load comparisons between levels within one group

Comparison	Adj. p-value
Super speed before vs. after	0.986
Speed before vs. after	1.000
Long-term sintered before vs. after	0.995
Zirkon before vs. after	**0.000**

Conclusions:

Based upon these in-vitro results the investigated reduced sinter times did not impair the thermo-mechanical fatigue behaviour, in-vitro longevity and failure loads of monolithic full anatomic Y-TZP crowns and can therefore be recommended.

Prospective clinical investigations are necessary to confirm the present results.