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Aging and Fatigue of Zirconia Oral Implants:

An In Vitro Investigation

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Disclosure

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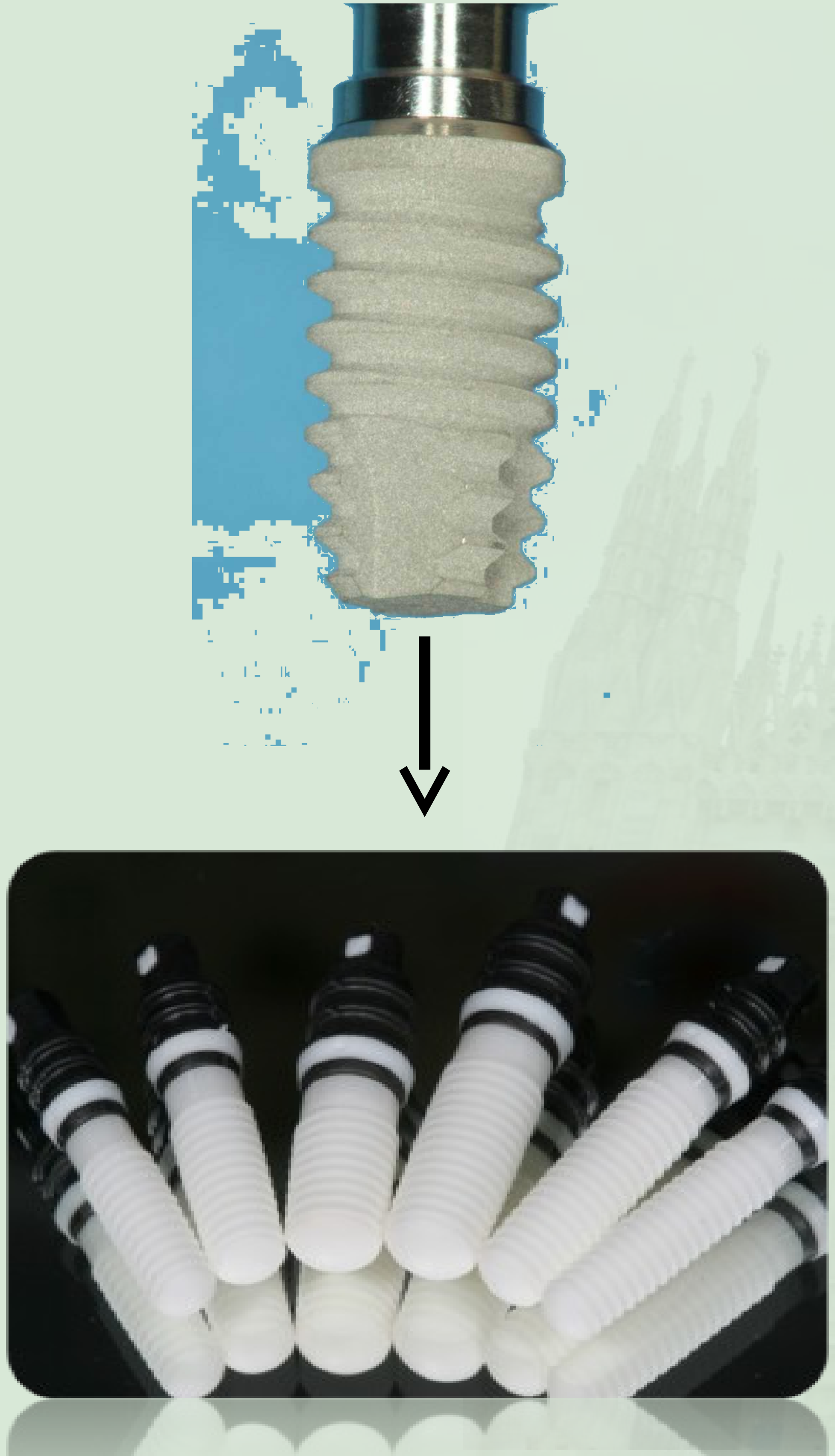
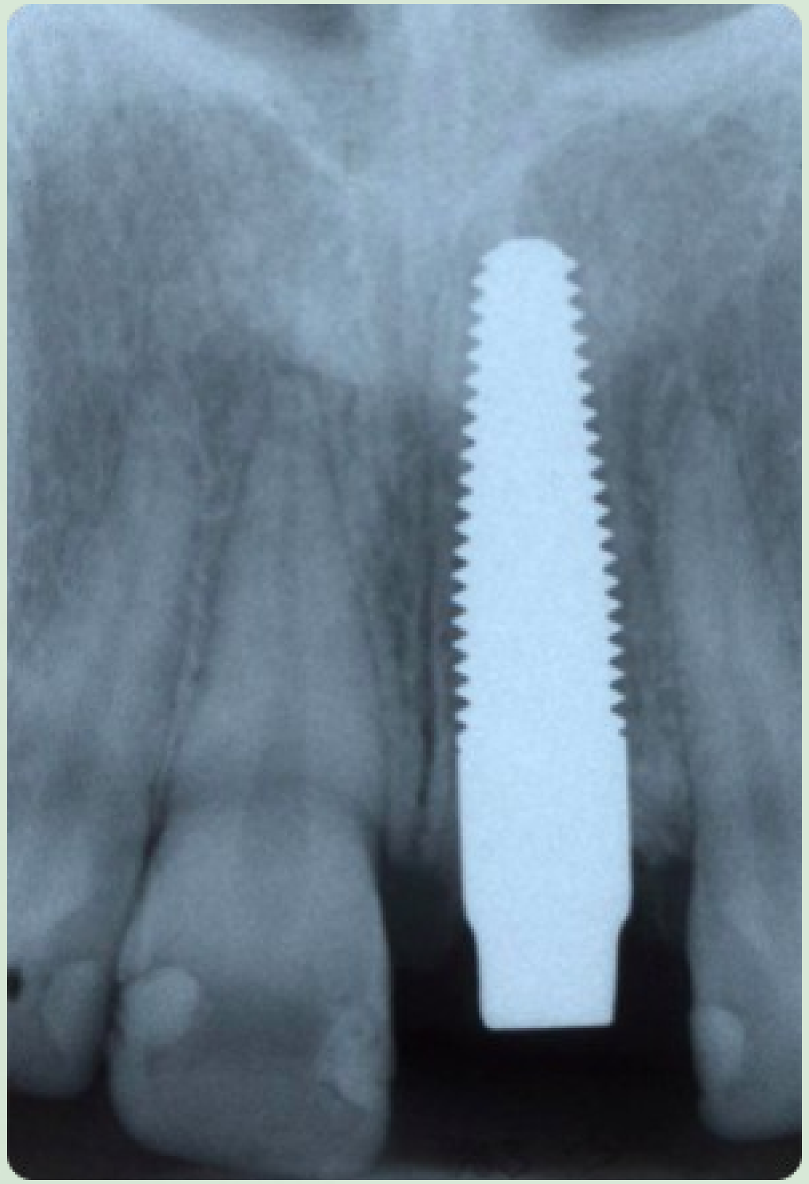
The implants were kindly provided by VITA Zahnfabrik, business unit vitaclinical, Bad Säckingen, Germany.

INTRODUCTION



- Y-TZP as possible replacement for titanium as oral implant material
- Ageing tendency of Y-TZP under hydrothermal influence (Deville et al. 2006)
- Mechanical stresses in addition may lead to further *t-m* transformation
- Zirconia oral implants are exposed to fluid, temperature & loading in the oral cavity (Kohal et al. 2012, 2013)

INTRODUCTION



AIM OF THE INVESTIGATION

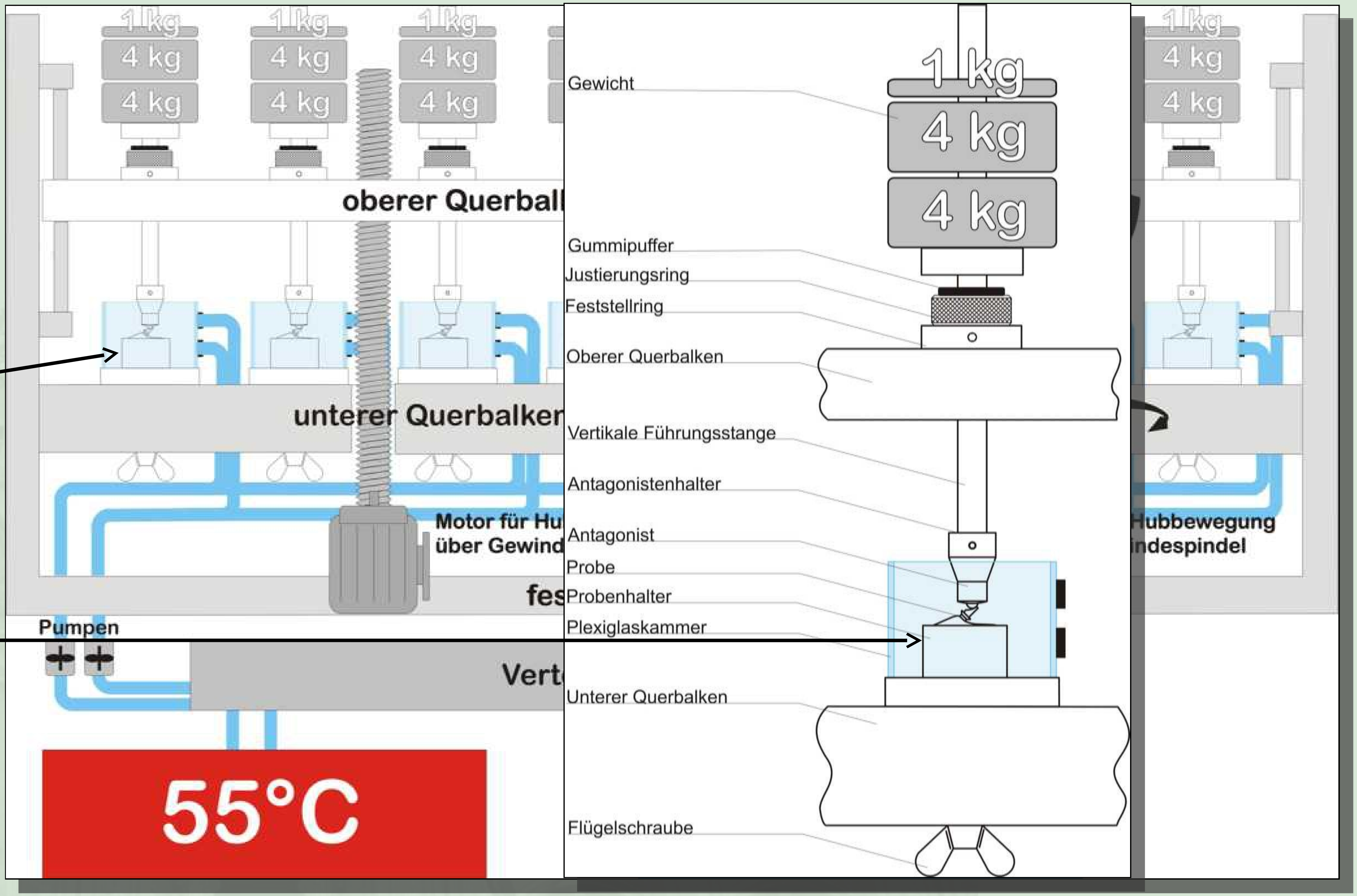
The aim of the in vitro (pilot) investigation was to evaluate the combined influence of hydrothermal and mechanical load on zirconia oral implants regarding the tetragonal-to-monoclinic phase transformation

MATERIALS AND METHODS: Implants

- 1 implant remained as delivered with no hydrothermal and mechanical load
- 8 zirconia embedded into Technovit resin and mounted in a modified chewing simulator
- all 8 implants were exposed to 80 °C hot water:
  - ✓ 3 implants were **not** mechanically loaded but exposed to the hot water for either 166 h (= 1.2 million loading cycles), 694 h (= 5 million cycles), and 1388 (= 10 million loading cycles)
  - ✓ 3 implants were **mechanically** loaded with **100 N** and exposed to the hot water for either 166 h (= 1.2 million loading cycles), 694 h (= 5 million cycles), and 1388 (= 10 million loading cycles)
  - ✓ 2 implants were **mechanically** loaded with **200 N** and exposed to the hot water for either 166 h (= 1.2 million loading cycles),

MATERIALS AND METHODS

embedded implant sample



artificial chewing simulator

MATERIALS AND METHODS: X-ray diffraction

- XRD CuKα radiation (Bruker D8 Advance):
  - range ($2\theta \in [27^0 - 33^0]$)
  - scan speed 0.2°/min and step size 0.02°
- experimental volume content of monoclinic phase *f* determined with:

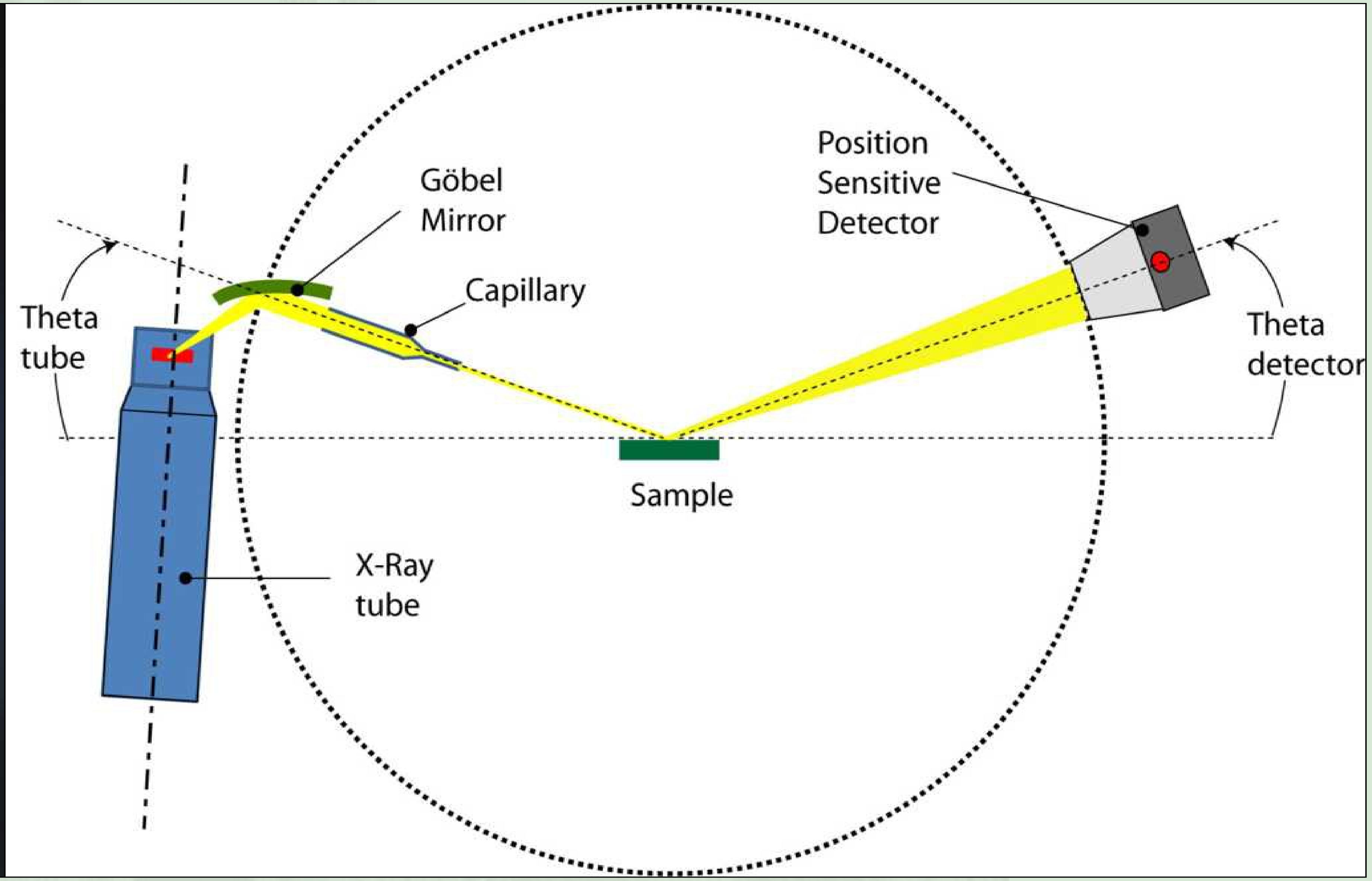
$$X_m = \frac{I_m(\bar{1}11) + I_m(111)}{I_m(\bar{1}11) + I_m(111) + I_c(111)}$$

$$f_{m,XRD} = \frac{1.311 X_{m,XRD}}{1 + 0.311 X_{m,XRD}},$$

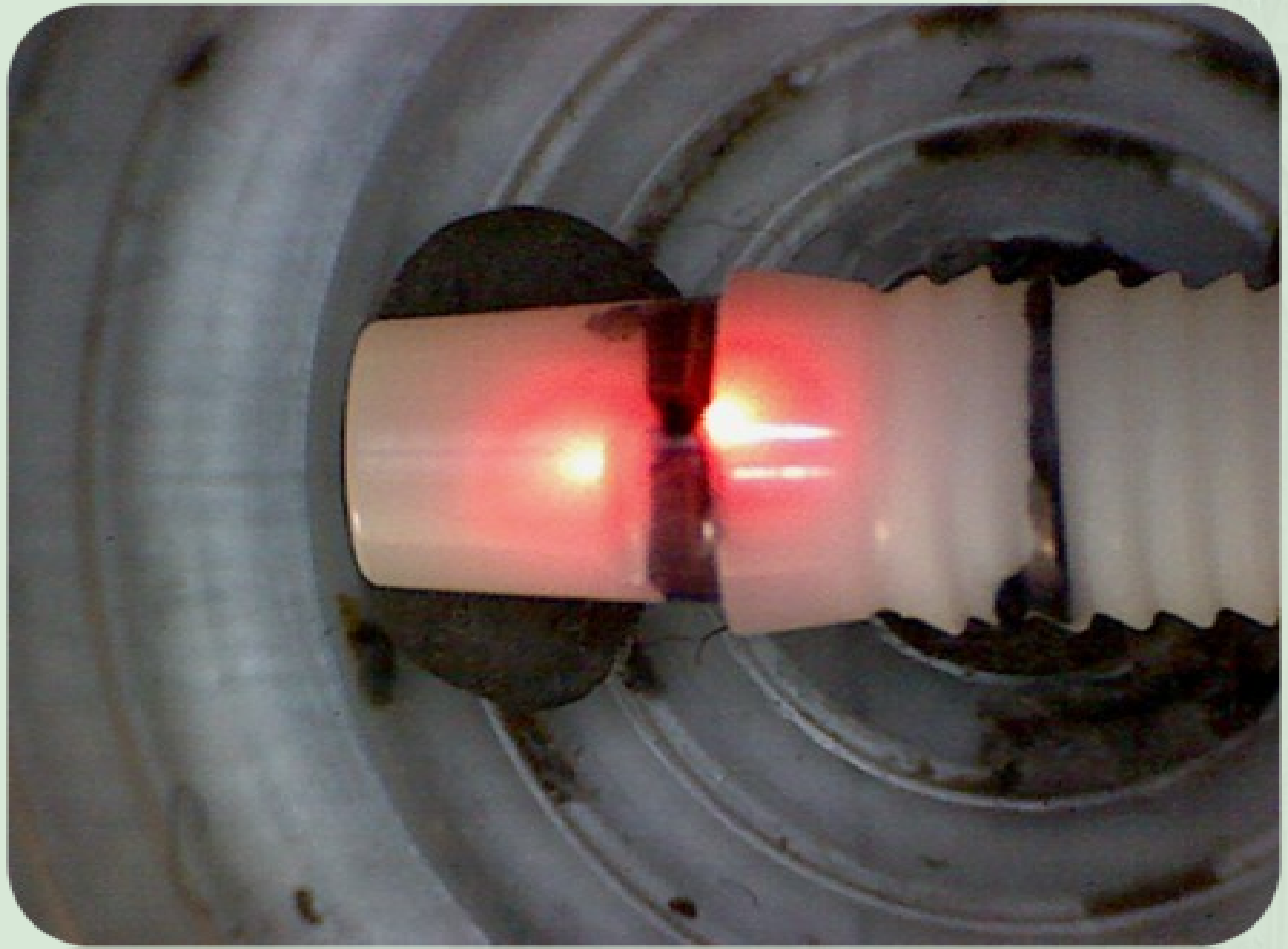
Toraya et al. 1984

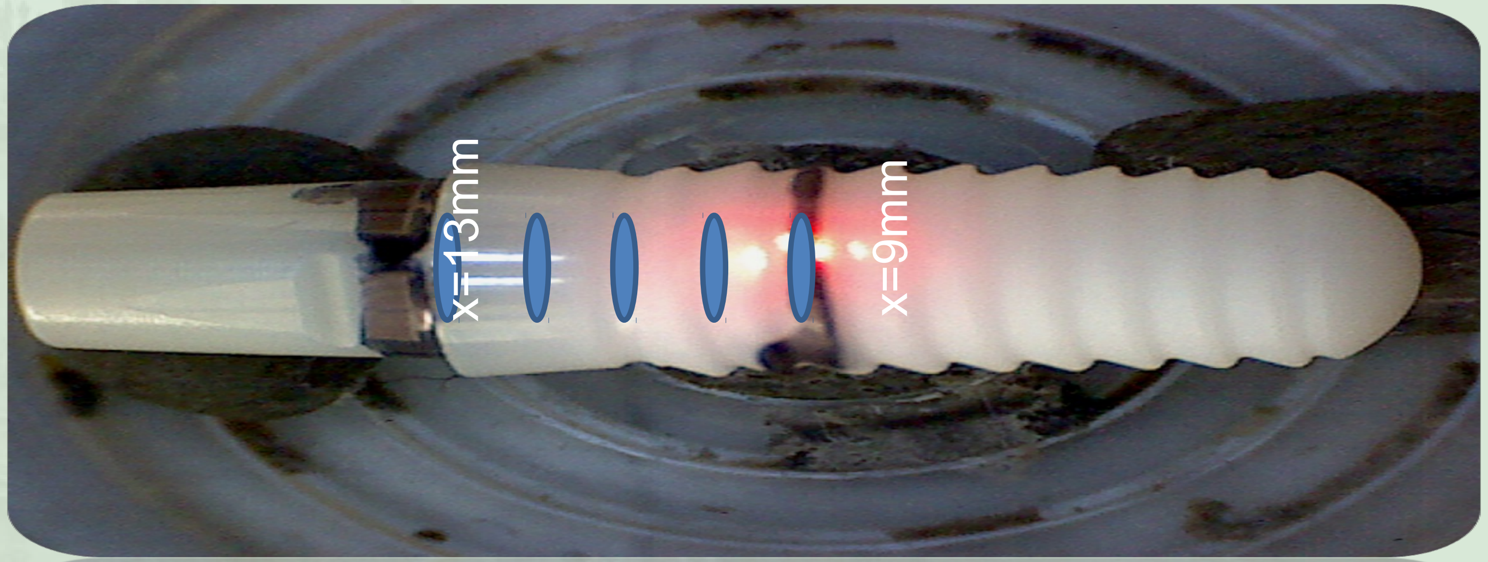
- tensile and compressive sides evaluated separately
- no statistical analysis due to the low number ot samples

MATERIALS AND METHODS: X-ray diffraction



MATERIALS AND METHODS: X-ray diffraction





RESULTS

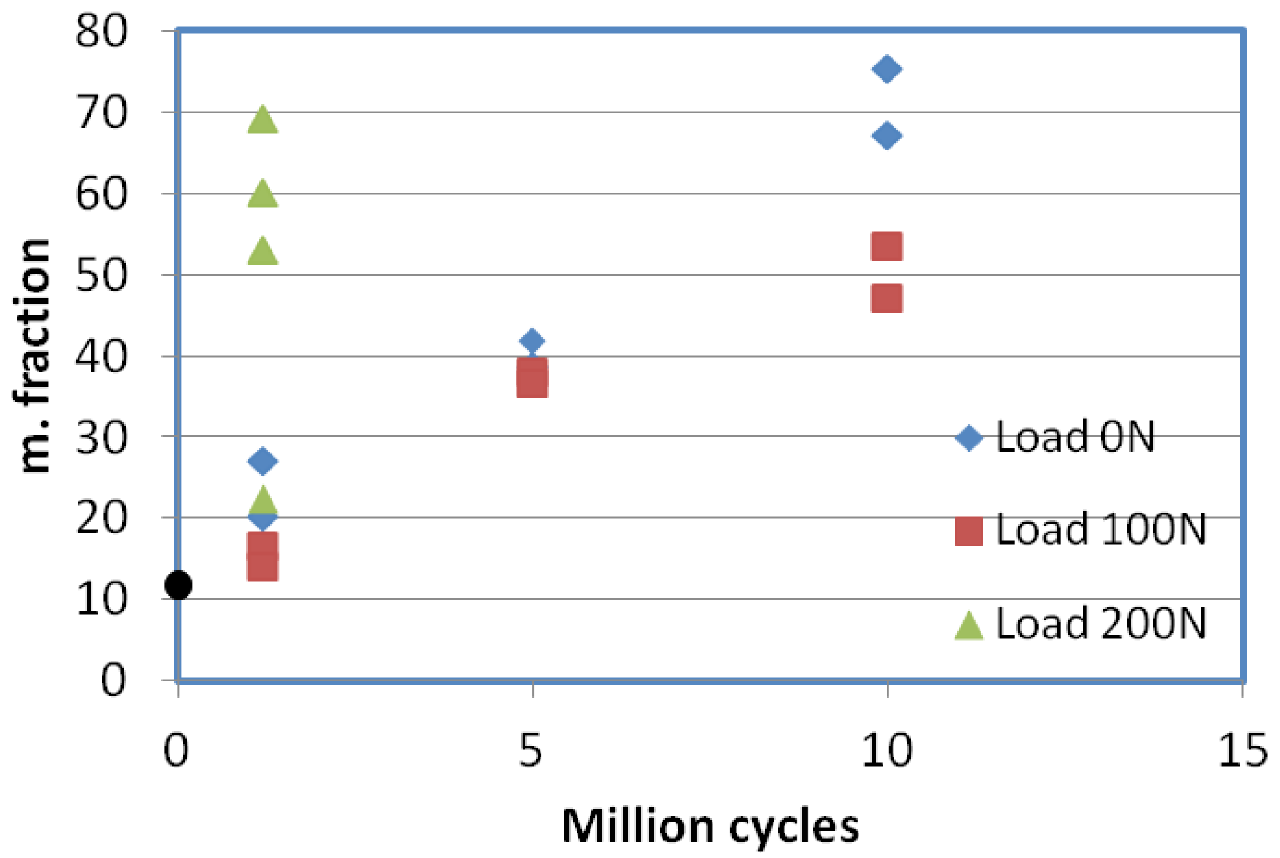
- No implant fracture in the artificial mouth
- Monoclinic phase fraction of the different implants

Load in N	Temperature in ^{0}C	Time	Tensile side	Compressive side
		cycles	Mean %	Mean %
0	0	0	11.7	11.7
0	80	1200000	20.3	27.2
0	80	5000000	41.8	38.7
0	80	10000000	67.2	75.3
100	80	1200000	16.7	14.1
100	80	5000000	38	36.6
100	80	10000000	53.4	47.2
200	80	1200000	22.3	53
200	80	1200000	60.1	69.3

RESULTS

- with increasing number of cycles (=time) monoclinic faction increased
- monoclinic phase fraction in non-loaded group higher than in the 100 N loaded group
- monoclinic phase fraction in non-loaded group lower than in the 200 N loaded group

Cycles	Side	Load 0N	Load 100N	Load 200N
0	tens./compr.	11,7		
1.2 mio	tensile	20,3	16,7	22.3(a)/60.1(b)
1.2 mio	compressive	27,2	14,1	53(a)/69.3(b)
5 mio	tensile	41,8	38	
5 mio	compressive	38,7	36,6	
10 mio	tensile	67,2	53,4	
10 mio	compressive	75,3	47,2	



DISCUSSION

- low number of specimens, non-statistical (pilot) character of investigation
- individual variations of implants in *t-m* transformation possible
- a low weight in addition to hydrothermal influence does not to seem to increase *t-m* transformation
- a longer exposure to hot water (cycles) increases *t-m* trans-formation (Chevalier et al. 2011, Keuper et al. 2013)
- the novel chewing machine seems to be appropriate for accelerated ageing of zirconia implants

TEMPERATURE – TIME EQUIVALENCE for zirconia ageing

- evolution of monoclinic fraction with time: $f_m = 1 - \exp(-(bt)^n)$
- *b* varies with temperature as: $b = b_0 \exp(-\frac{Q}{RT})$
- same f_m at temperatures T_1 and T_2 if $b_1 t_1 = b_2 t_2$, or: $t_2 = t_1 . \exp\left[-\frac{Q}{R}\left(\frac{1}{T1} - \frac{1}{T2}\right)\right]$

Cycles	Time at 80°C	Represents X time at 37°C (Ageing)
1.2 M	166 h	2 years and 2 months
5 M	694 h	9 years
10 M	1388 h	18 years

CONCLUSION

- Exposure time to hydrothermal ageing seems to be the driving force for *t-m* transformation
- Loading may add to the transformation from a certain threshold on

Thank you for your kind attention

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