Determination of stability of two-piece zirconium dioxide implants using the rotational oscillation test

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Purpose

The clear biological advantages of all ceramic two-piece ZrO_2 implants are possibly compromised by a lower stability of the interface area. Therefore, the mechanical stability of this type of implants should be investigated and additionally compared with that of titanium implants.

Method

Mechanical loading of all-ceramic implants was performed by the well-engineered dynamic rotational oscillating method (DIN 1311-2) that has already been introduced to dentistry [1, 2].

Protocol

In the present investigation ZrO_2 implants were subjected to pseudo-realistic loads of 15 Ncm (fatigue test, 3 × 20 min) and 50 Ncm (crash test, 2 × 10 min) considering a life-time mode.

Test parameters

Before, during and after the stress tests the following parameters were ascertained:

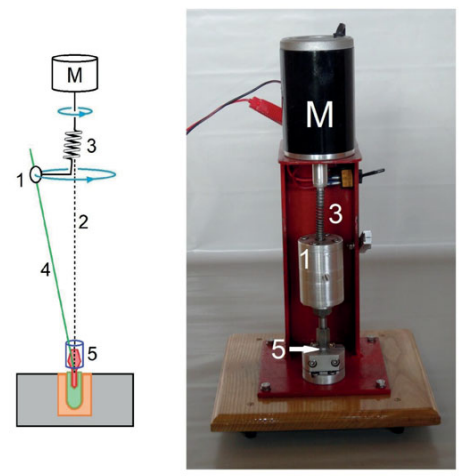
- Fractures of the interface components
- Loosening of the connection screw
- Tilting and rotational clearance of the abutment

Specimens

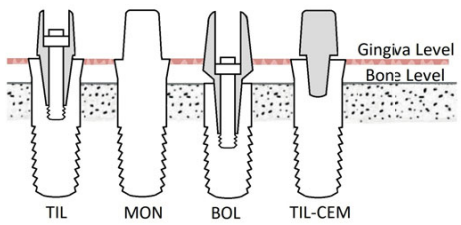
Six samples each of 10 different types of specimens were subjected to the study:

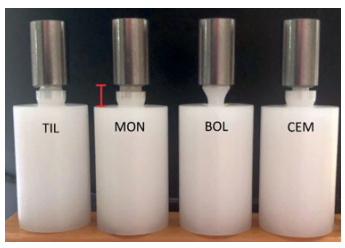
- MON monophase implant (control)
- TIL-CEM^{TC} tissue level type (cemented+TC)
- BOL-Ti bone level type with Ti-screw
- BOL-Zr bone level type with Zr-screw
- TIL-Ti tissue level type with Ti-screw
- TIL-Zr tissue level type with Zr-screw
- BOL-Ti^{TC} BOL-Ti (screw cemented+TC)
- BOL-Zr^{TC} BOL-Zr (screw cemented+TC)
- TIL-Ti^{TC} TIL-Ti (screw cemented+TC)
- TIL-Zr^{TC} TIL-Zr (screw cemented+TC)

Test system



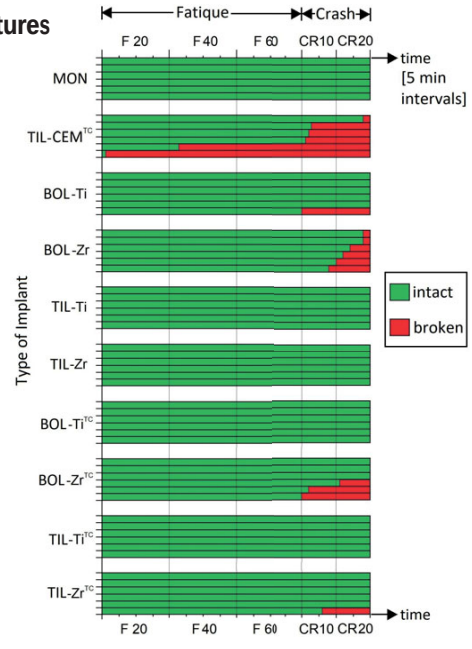
M: drive motor, 1: eccentric mass, 2: device axis, 3: spiral spring for transmitting rotation, 4: axis of the precession oscillating cylinder, 5: test specimen fixed on the device axis.





Results

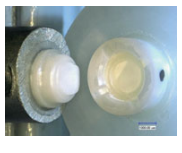
Fractures



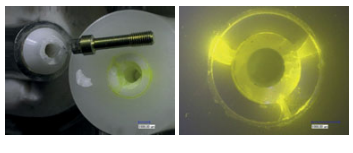
- 2 fractures in the fatigue cycles
  15 fractures in the crash cycles
- Overall survival rate 71.7 %
- Type TIL-CEM^{TC} mechanically unstable
- Zr screws are source of lower stability
- Cemented screws enhance stability
- Ultimate breaking resistance could be assessed for:
  MON (control)
  TIL-Ti
  TIL-Ti^{TC}
  TIL-Zr
  BOL-Ti^{TC}

Typical fracture patterns of the test specimen

TIL-CEM^{TC}

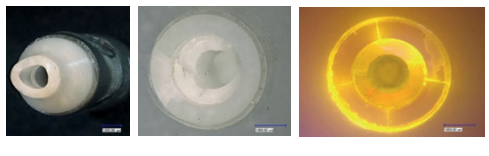


BOL-Ti



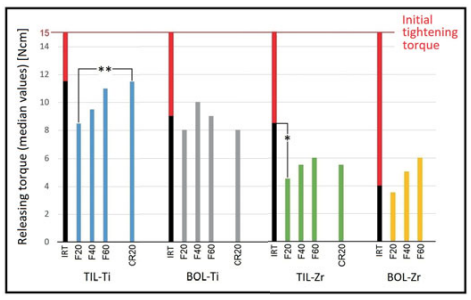
TIL-Zr^{TC}

BOL-Zr

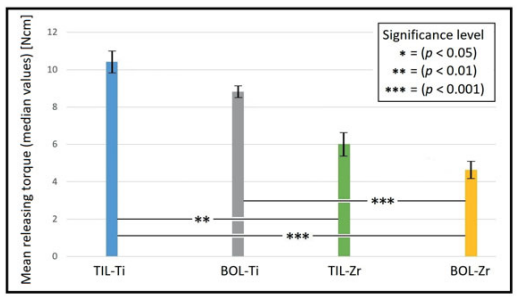


Results (cont.)

Releasing torque of the connection screw

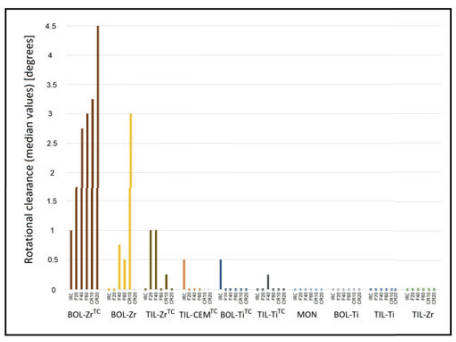


- All screws were tightened using a torque of 15 Ncm. Under fatigue stress the torque decreased distinctively in case of ZrO_2 screws compared to that of Ti screws, both revealing a slight increase of releasing torque along with further stress.

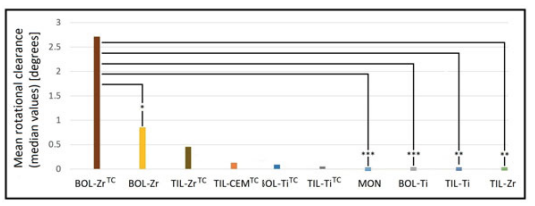


- Upon fatigue stress, the mean releasing torque of Ti screws averaged to 64 % of the initial tightening torque and was significantly higher than that of ZrO_2 screws showing an average of 36 %, respectively.

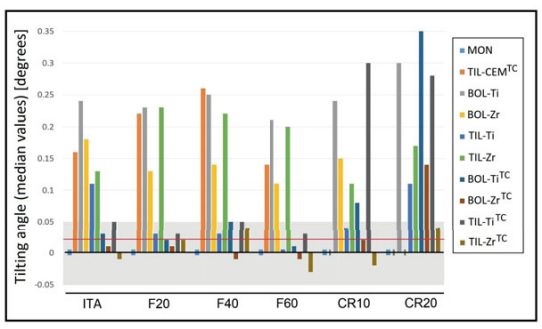
Rotational clearance



- Significantly increased rotational clearance was seen in bone level implants with ZrO_2 screws.

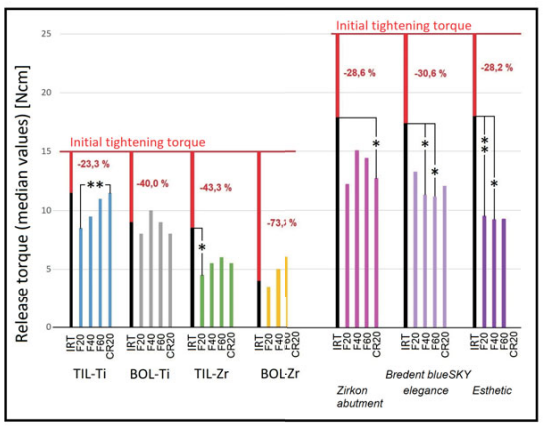


Tilting angle



- All implants with cemented screws showed no tilting, regardless of the screw material.
- Considering all test criteria, superior tilting stability of the connection between fixture and abutment could be seen in tissue level implants with titanium screws.

Comparison of ZrO_2 implants with titanium implants both subjected to the rotational oscillating method [2]



- Under the same test conditions, the ZrO_2 implants showed higher stability, lower tilting and rotational clearance as well as a smaller number of fractures.
- Due to the higher tightening torque, Titanium implants showed an increased releasing torque resulting in a higher immobilization of the abutment screw.

Conclusion

Within the limitations of this study, it has been shown that

- the dynamic rotational oscillating loading method (DIN 1311-2) can be used to simulate long-term loading of implants within a short period of time.
- compared to titanium implants, ZrO_2 implants showed largely better results with regard to fracture strength, wear and loosening effects in the area of the connection between fixture and abutment.

References

[1] DIN 1311-2, Schwingungen und schwingungsfähige Systeme - Teil 2: Lineare, zeitinvariante, schwingungsfähige Systeme mit einem Freiheitsgrad (2002-08), Beuth-Verlag, www.beuth.de

[2] Weißweiler D, Niedermeier W (2021). Prüfung der Stabilität von Implantat-Abutment-Verbindungen im Rotationsschwinger-Test. *ZWR-Das Deutsche Zahnärzteblatt* 130:536-45.