Evaluation of the Interface Between Titanium-Zirconium Alloyed Dental Implants with Different Abutment Materials: An In-vitro Biomechanical Study.

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Basic research

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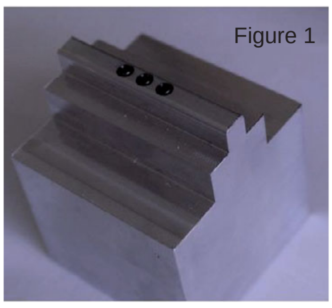
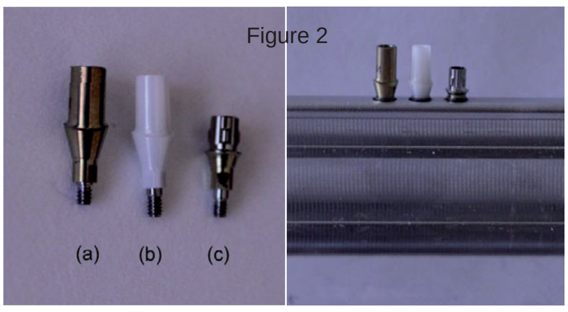
Background and Aim

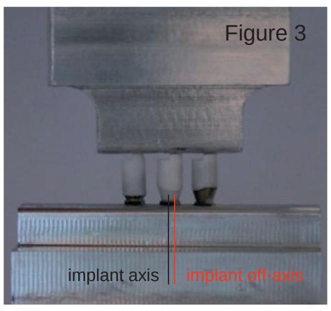
For long term success of implant-supported restorations, the physical/mechanical properties of the relationship in the implant-abutment (I-A) interface is crucial to prevent biological or mechanical complications or both. Accordingly, regardless of I-A connection type (i.e conical, butt joint), material properties and their interaction under function is also important. This refers to machining tolerance of the implant and the abutment at fabrication and their behaviour to the micro-movements. A recent systematic study confirmed material differences at the I-A interface likely to lead to microleakage, and zirconium abutments with titanium implants are not suggested (1). Today, specifically narrow-diameter implants with improved mechanical properties by alloying titanium with zirconium is commonly used specifically at the functional zone. This option even more complicates the mechanical behaviour at the I-A interface due to material differences. Although the I-A interface and the wear characteristics of Ti implants when coupled with Ti or Zr abutments have been presented earlier(2), the the joint stability between Ti-Zr implant with Zr- or Ti-abutment is unclear. The aim of this study was to explore the effect of Ti-Zr implant material on the interface between 1-piece zirconia and two different titanium abutments using scanning electron microscopy (SEM).

Methods and Materials

Study models representing residual alveolar bone were machined from Type IV aluminum. Three study models were prepared, one for the control samples before loading and two for the test samples after loading. Each model received three Ø 3.3X10mm bone level Ti-Zr implants (Roxolid® ,Institut Straumann AG, Basel, Switzerland) (Fig.1). Then, one-piece zr- and ti-abutments and a ti-base abutment were separately torque tightened to the implants to 35Ncm manually using a ratchet (Fig.2). Following the digital impression with a laboratory scanner (inEOS scanner, Dentsply Sirona, Charlotte, NC), the experimental zirconium oxide copings were manufactured using CAD/CAM system for each abutment. Occlusal surfaces of the copings were modified to create axially lateral loading to the implant axis. Screw access holes were created on the crowns to facilitate the removal of the abutments after the cyclic loading. The copings were adhesively luted. The test group implant-abutment assemblies were subjected to cyclic loading of 30 N at 2 Hz for 500,000 cycles using a servohydraulic test system (MTS Landmark, MTS Testing Solutions) in a dry environment. (Fig.3) Following completion of fatigue testing, samples were removed from the aluminum block and longitudinally sectioned to expose mating implant and abutment surfaces. (Fig.4)







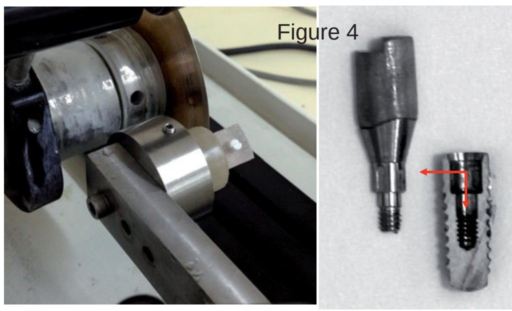


Fig.1. Bone-level narrow-diameter implants placed into a study model

Fig.2. 1-piece zr- and ti- abutments (a and b) and ti-base abutment(c) (left), and connected abutments to the implants on a model (right)

Fig.3. Dynamic loading on the zirconium copings designed for lateral axial loading to implant axis

Fig.4. Preparation of a loaded sample (left) and longitudinally sectioned I-A complex for evaluation of the mating surfaces (right)

Each I-A interface surface was inspected as pairs under an SEM (JSM-6400 Electron Microscope, JEOL Ltd) equipped with an x-ray microanalysis system and semaphore digitizer (NORAN System SIX, Thermo Electron Scientific Instruments) to identify signs of wear, fracture, and clarity. The control group surfaces were analysed for both abutment and implant at two regions: cervical and apical, whereas the test group surfaces were analysed for both abutment and implant also based on the loading axis: cervical loading side and apical loading side, cervical contralateral side and apical contralateral side (Fig.5)

Results

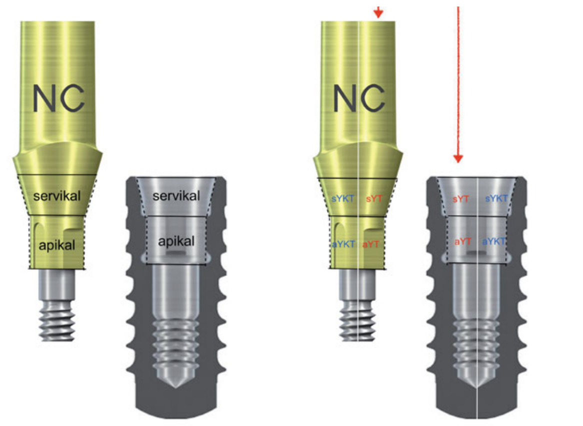


Fig.5. Definition of surfaces for SEM analysis;
Left: control group (without loading)
Right: test group (with loading): red side indicates loading side, blue contralateral side

Table.1. Result of control and test group

			Abutment			Implant		
				Titanium			Titanium	
			Zirconium One-piece	One-piece	Hibrid	Zirconium One-piece	One-piece	Hibrid
Control Group	Cervical region		P+	P+	P+	P+	P+	P+
	Apical region		P+	P+	P+	P+	P+	P+
Test Group	Cervical Region	loading side	P+ D+	W+	W+	W+ D+ C+	P+ D+	P+ D+
		contra-lateral side	P+ D+	S+ W+	S+ W+	W+ D+ C+	P+ D+	P+ D+
	Apical Region	loading side	P+	P+	P+	P+	P+	P+
		contra-lateral side	P+	P+	P+	P+	P+	P+

P: Protrusion / W: Wear / D: Debris / S: Scratches / C: Chipping

All samples completed the fatigue test without any coping, abutment and implant fracture. All copings were recorded stable with zero mobility according to periotest values. I-A interfaces with 1-piece ti-abutment and ti-base abutments presented similar mechanical reactions. Wear areas, deformations, and scratches were apparent on both titanium abutment surfaces, whereas large coated areas were noticeable on the corresponding implant surfaces due to titanium transfer (tattooing). Both implant- and abutment-surfaces at 1-piece zr-abutment samples presented similar changes. Zr-abutment surfaces were almost lack of any deformation, whereas small wear areas and chipping were noted at the corresponding implant surfaces. The results of the control and test groups are shown in Table 1.

I-A interface for both 1-piece and ti-base titanium abutments presented scratched areas at the contralateral loading side cervical region, while wear and debris were observed at I-A connection (Fig. 6.left), and increased debris was evident on the corresponding implant mating surfaces (Fig. 6, right).

Debris and protrusion were observed at the 1-piece zr abutment surface, both loading and contralateral side, at the cervical region (Fig. 7, left), and wear, chipping, and debris were recorded on the mating surface of the implant (Fig. 7, right).

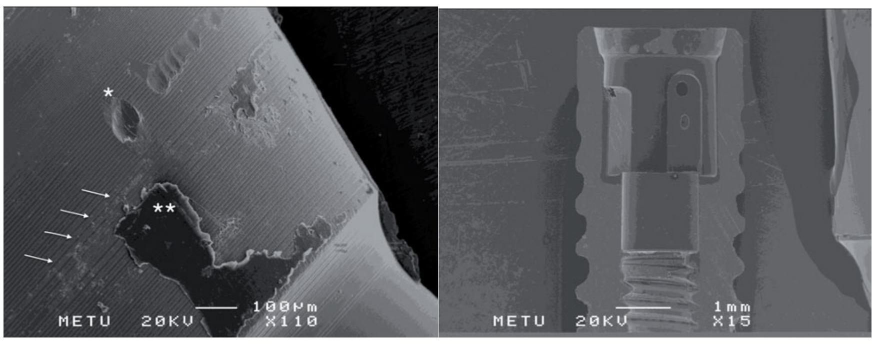


Fig.6. Left: wear (arrow), *scratch,**debris at 1-piece ti abutment surface x110 magnification
Right: debris at implant mating surface

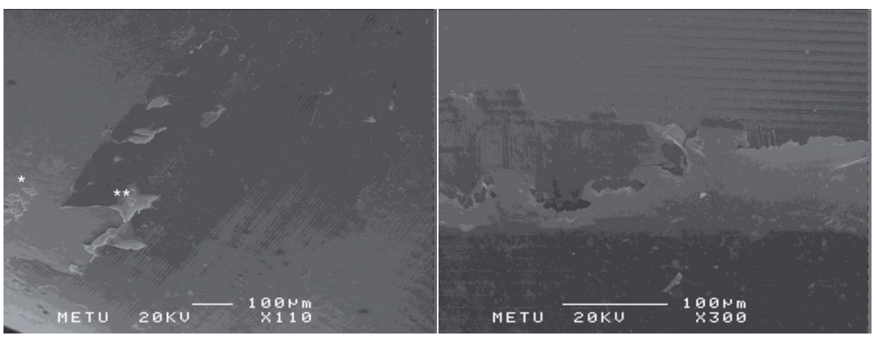


Fig.7. Left: *protrusion,**debris at 1-piece zr- abutment surface x110 magnification
Right: wear, chipping and debris at implant mating surface

Conclusion

As Ti-Zr implants connected with one-piece Zr abutment displayed favourable mechanical congruence, Ti implants alloyed with zirconia implants may be considered for cases where restorations are supported with one-piece Zr abutments.

References

(1) Microleakage at the Different Implant Abutment Interface: A Systematic Review J Clin Diagn Res. 2017 Jun;11(6):ZE10-ZE15.

(2) A pilot study of joint stability at the zirconium or titanium abutment/titanium implant interface Int J Oral Maxillofac Implant Mar-Apr 2014;29(2):338-43.