Supplementary Material

*(Continues)*

|  |
| --- |
| Table 1. Description of experimental studies in tribocorrosion focused on implant dentistry |
| Author (year) | **Biomaterial** | **Tribological test** | **Working parameters** | **Response variable** | **Main findings** |
| **Mechanical parameters** | **Corrosion parameters** |
| Albayrak et al., 2013 | • cpTi untreated • cpTi Nitrided • cpTi Duplex treated | • Type: reciprocating ball on flat tribometer (Turkyus PODTW&RWT ASTM G133-02) • Counterbody: AL2O3 ball (Ø 6 mm) • Potentiostat: 3-electrode Gamry Series G 750 potensiostat | • Applied Load: 5 N • Frequency: 1 Hz • Duration/cycles: 4 x 10⁴ s • Stroke distance: 8 mm | • Electrolyte solution: SBF • Temperature: 37 °C • Current: -1000 mV Ref. • Surface area: 0.36 cm² and 0.85 cm² | • OCP (mV vs Ref.) • COF (µ) • Material wear loss (mm³) | The best tribocorrosion behavior was obtained from the duplex treated specimens. |
| Alves et al., 2013 | • cpTi • TiO₂ anatase • TiO₂ rutile | • Type: pin-on-disc tribometer (CETR– UMT-2) • Counterbody: AL2O3 ball (Ø 10 mm) • Potentiostat: 3-electrode Gamry Instruments potentiostat (Ref 600) | • Applied Load: 1.5 N • Frequency: 2 Hz • Duration/cycles: 250 s and 1814 s • Stroke distance: 10 mm | • Electrolyte solution: 8 g lˉ¹ sodiumchloride solution • Current: +244 mV/NHE • Time/cycles: 250 s and 1814 s | • COF • OCP E (V vs SCE) • Wear (SEM) | Better tribocorrosion behavior was noticed on increasing the calcium acetate concentration. |
| Alves et al., 2014 | • cpTi • PEO 3 A/dm² • PEO 8 A/dm² | • Type: pin-on-disc reciprocating tribometer • Counterbody: Al2O3ball (Ø 10 mm) • Potentiostat: 3-electrode Autolab, Eco Chemie PGSTAT30 | • Applied Load: 2N • Frequency: 2Hz • Duration/cycles: 720 s • Stroke distance: 3mm | • Electrolyte solution: Artificial saliva • Temperature: 37 °C • Current: 0.207 V vs SHE | • OCP (V vs. Ag/AgCl) • COF • Wear volume | The tribocorrosion behavior of cpTi was improved after PEO treatments. |
| Alves et al., 2017 | • cpTi • NT • NT-Ca/P/Zn | • Type: reciprocating pin-on-disk CETR tribometer (Model UMT 2, Campbell, California, USA) • Counterbody: Al2O3ball (Ø 10 mm) • Potentiostat: 3-electrode potentiostat | • Applied Load: 1 N • Frequency: 1 Hz • Duration/cycles: 1800 s • Contact stress: 400 MPa • Stroke distance: 650 μm | • Electrolyte solution: Fusayama's artificial saliva (pH = 5.5) • Temperature: 37 °C • Current: +244 mV vs. NHE • Surface area: 0.63 cm² | • OCP (V vs SCE) • COF • Wear volume and track profile | The tribo-electrochemical behavior of bio-functionalized TiO2 nanotubes was significantly improved. |
| Alves et al., 2018 | • TiO₂ NTs • NT-Ca/P/Zn#1 • NT-Ca/P/Zn#2 | • Type: reciprocating pin-on-disk CETR tribometer (Model UMT 2, Campbell, California, USA) •Counterbody: Al2O3ball (Ø 10 mm) • Potentiostat: 3-electrode potentiostat | • Applied Load: 1 N • Frequency: 1 Hz • Duration/cycles: 1800 s • Contact stress: 400 MPa • Stroke distance: 650 μm | • Electrolyte solution: Fusayama's artificial saliva (pH = 5.5) • Temperature: 37 °C • Current: +244 mV vs. NHE • Surface area: 0.63 cm² | • OCP (V vs SCE) • COF • Wear volume (µm³ x 10⁶) • Track profile | Bio-functionalized TiO2 NTsprovide corrosion protection and resistance to mechanical degradation. |
| Banu et al., 2008 | • NiCrMo | • Type: pin-on plate with frictional force via a bidirectional load cell • Counterbody: NiCrMo pin (0.15 cm² contact area) • Potentiostat: platinum net counter-electrode and a SCE electrode as a reference electrode | • Applied Load: 7.33 N/mm² • Speed: 500, 1000 and 1500 rot/min | • Electrolyte solution: artificial saliva with SiC abrasive particles • Current: –1.0 V to 1,0 V • Time/cycles: 24 h • Surface area: 0.7 cm² | • OCP (mV/SCE) • Rate of anodic dissolution • Polarization curves mA/cm² | Straining and wear of the NiCrMo dental alloys during mastication have not an important influenceon their corrosion in neutral biofluids. |
| Benea et al., 2017 | • Ti–10Zr • TiO₂–ZrO₂ | • Type: unidirectional pin-on-disc tribometer •Counterbody: Al2O3ball (Ø 7 mm) • Potentiostat: 3-electrode Solartron 1287 | • Applied Load: 5 N • Speed: 120 rpm • Duration/cycles: 30 min/5000 cycles | • Electrolyte solution: Fusayama's artificial saliva (pH = 4.8) • Temperature: 23 °C • Current: 200 mV vs.SHE • Time/cycles: 30 min/5000 cycles | • OCP E (V vs Ag/AgCl) • COF | The tribocorrosion performance of anodic formed porous TiO2–ZrO2 surface is higher compared with that of untreated Ti–10Zr alloy surface. |
| Benea et al., 2013 | • Ti-6AI-4V | • Type: reciprocating fretting tribometer • Counterbody: Al2O3ball (Ø 10 mm) • Potentiostat: 3-electrode Solartron 1287 | • Applied Load: 5 N • Frequency: 1, 3 and 5 Hz • Duration/cycles: 5000 cycles • Stroke distance: 200 µm | • Electrolyte solution: Fusayama's artificial saliva • Current: 200 mV vs. SHE • Time/cycles: 300s, 5000 cycles and after 600s • Surface area: 1 cm² | • OCP E (V vs Ag/AgCl) • Coefficient of friction • Wear tracks | The fretting frequency affects the wear volume of Ti-6AI-4V alloy sliding against balls, being directly proportional to the fretting frequency. |
| Benea et al., 2015 | • Ti–10Zr • TiO₂–ZrO₂ | • Type: unidirectional pin–on–disc tribometer • Counterbody: Al2O3ball • Potentiostat: 3-electrode potentiostat | • Applied Load: 2N • Speed: 120 rpm • Duration/cycles: 5000 cycles | • Electrolyte solution: Fusayama's artificial saliva (pH = 4.8) • Temperature: 23 °C • Current: 200 mV vs.SHE • Time/cycles: 5000 cycles | • OCP E (V vs Ag/AgCl) • COF | The controlled anodic oxidation method improves the wear properties of Ti–10Zr alloy in the presence of a bio-simulated environment. |
| Branco et al., 2019 | • Ti–6Al–4V • Zirconia | • Type: reciprocating CSM nanotribometer (CSM Instruments SA, Peuseux, Switzerland) • Counterbody: Ti Ball and Zr ball • Potentiostat: 3-electrode Ref 600 potentiostat (Gamry Instruments, Warminster, PA, USA) | • Applied Load: 20 mN • Frequency: 2 Hz • Duration/cycles: 1300 cycles • Contact stress: 150/160 MPa • Stroke distance: 1 mm | • Electrolyte solution: dry, water, artificial saliva solution and human saliva • Time/cycles: 1300 cycles | • OCP • COF • Wear volume (mm³/Nm) | The most adequate configuration to study the tribological behavior of Ti6Al4V implant and ZrO2 abutment in vitro is a metallic ball sliding on a ceramic plate. |
| Table 1. Description of experimental studies in tribocorrosion focused on implant dentistry |
| Author (year) | **Biomaterial** | **Tribological test** | **Working parameters** | **Response variable** | **Main findings** |
| **Mechanical parameters** | **Corrosion parameters** |  |
| Bryant and Neville, 2017 | • CoCrMo | • Type: reciprocating electromechanical fretting tribometer • Counterbody: CoCrMo ball • Potentiostat: PGSTAT101; Metrohm, Switzerland  | • Frequency: 1 Hz • Duration/cycles: 300 s, 3000 cycles, 500 s • Contact stress: 1.0, 0.6, 0.4 GPa • Stroke distance: 10, 20, 30, 40, 50 µm | • Electrolyte solution: PBS (pH = 7.4) • Temperature: 37 °C • Current: 20–50 mV of Ecorr • Time/cycles: 300 s, 3000 cycles, 500 s | • Potencial E corr (V vs Ag/AgCl) • Total mass loss (mg) • Displacement amplitudes (µm) | There is a relationship between slip mechanism and the contributors to tribocorrosion degradation. |
| Buciumeanu et al., 2017 | • Ti–6Al–4V • Ti6Al4V-HA | • Type: reciprocating ball-on-plate Bruker-UMT-2 tribometer • Counterbody: Al2O3ball (Ø 10 mm) • Potentiostat: Gamry Potentiostat / Galvanostat (Ref 600) | • Applied Load: 1 N • Frequency: 1 Hz • Duration/cycles: 1800 s • Contact stress: 429 MPa • Stroke distance: 3 mm | • Electrolyte solution: Fusayama's artificial saliva • Temperature: 37 °C • Time/cycles: before 60 min, during 30 min, after 60 min | • OCP (V vs SCE) • COF • Wear rate (mm3 N−1 m−1) | The introduction of HA seems to be a good choice for Ti6Al4V alloy, as the combination of these lead to improvement on both wear and corrosion behavior. |
| Buciumeanu et al., 2016 | • CoCrMo | • Type: reciprocatingball-on-platetribometer (Bruker-UMT-2) • Counterbody: Al2O3ball (Ø 10 mm) • Potentiostat: 2-electrode Gamry Potentiostat/Galvanostat (Ref 600) | • Applied Load: 1 N • Frequency: 1 Hz • Duration/cycles: 1800 s • Contact stress: 429 MPa • Stroke distance: 3 mm | • Electrolyte solution: Fusayama's artificial saliva • Temperature: 37 °C • Time/cycles: before 60 min, during 30 min, after 60 min | • OCP (V vs SCE) • COF • Wear rate (mm3 N−1 m−1) | The processing conditions play a relevant role on tribocorrosion behavior of CoCrMo. |
| Corne et al., 2019 | • Ti-grade 4 X Ti-6Al-4V • Ti-6Al-4V X Ti-6Al-4V • Ti-grade 4 X Zr Y-TZP • Ti-6Al-4V X Zr Y-TZP | • Type: Fretting-corrosion machine Mines Saint-Etienne and TA instruments™, Company (New Castle, USA) • Counterbody: Ti-6Al-4V or Zr Y-TZP • Potentiostat: 2-electrode PARSTAT 2263 potentiostat | • Applied Load: 127.5 N or 85 N • Frequency: 1 Hz • Duration/cycles: 57,600 cycles • Contact stress: 80 MPa • Stroke distance: 40 μm | • Electrolyte solution: human saliva • Temperature: 20 °C • Current: E = +242 mV/SHE • Time/cycles: OCP before 1 h, fretting 16 h, OCP during 20 min | •OCP (V vs SCE) • Wear track area (mm³/Nm) | Ti vs. Y-TZP clearly appears as the best performance couple under fretting corrosion conditions in human saliva. |
| Correa et al., 2016 | • cpTi • Ti-15Zr-7.5Mo • Ti-15Zr-15Mo | • Type: pin-on-disk tribometer CETR-UMT2 • Counterbody: Al2O3ball (Ø 10 mm) • Potentiostat: 3-electrode potentiostat Radiometer Copenhagen (PGP201) | • Applied Load: 1.5N • Frequency: 2 Hz • Duration/cycles: 30 min • Stroke distance: 5 mm | • Electrolyte solution: SBF solution • Temperature: 37 °C • Time/cycles: 30 min | • OCP) (V vs SCE) • COF | Ti-15Zr-7.5Mo could have potential for dental applications. |
| Cui et al., 2019a | • TiN • TiZrN | • Type: reciprocating ball-on-disc tribometer (CSM, Switzerland) •Counterbody: Al2O3ball (Ø 6 mm) • Potentiostat: 3-electrode potentiostat (Zennium, Germany) | • Applied Load: 5 N • Frequency: 1 Hz • Duration/cycles: 120 min • Contact stress: 1490 MPa and 1540 MPa | • Electrolyte solution: Hank's solution with and without 25% calf serum • Temperature: 37 °C • Current: −150 mV, +50 mV, +250 mV • Time/cycles: 120 min • Surface area: 1 cm² | • OCP E (V vs SCE) • COF • Corrosion current i (μΑ) • Wear track depth (μm) • Wear rate (×$10^{-7}$mm³/Nm) • Volume loss (×$10^{-3}$mm³) | Nanocrystalline TiZrN coating is very suitable for surface modification material of Ti alloy which endure large load and serious wear. |
| Cui et al., 2019b | • Ti6Al4V • Ti6Al4V-TiN | • Type: linear reciprocating ball-on-disc tribometer (CSM, Switzerland) • Counterbody: Si₃N₄ ball • Potentiostat: 3-electrode potentiostat (Zennium, Germany) | • Applied Load: 5 N • Frequency: 1 Hz • Duration/cycles: 180 min • Contact stress: 350 GPa • Stroke distance: 10 mm | • Electrolyte solution: Hank’s solution • Temperature: 37 °C • Time/cycles: OCP 1 h to stabilize, 180 min • Surface area: 1 cm² | • OCP (OCP/mV) • COF • Lost volumes ΔVT/cm³ | Mechanical wear is the main tribocorrosion mechanism of the coated TC4 alloy. |
| Dalmau Borrás et al., 2019 | •Ti/ZrO2 pair | • Type: pin-on-disk tribometer • Counterbody: Zr₂O + 3M Y₂O₃) ball • Potentiostat: 3-electrode potentiostat | • Applied Load: 5 N • Speed: 60 rpm, 6.28 mm/s • Contact stress: 647 MPa and 584 MPa | • Electrolyte solution: artificial saliva (pH 6.5) • Temperature: 37 °C • Time/cycles: before 300 s, 1800 s potential, 3600 s after stabilization | • OCP (V Ag/AgCl) • COF • Wear volume (mm³/Nm) • Wear track (SEM) | Zirconia did not suffer any damage under all the studied conditions and oxidized titanium was transferred to the ball at anodic applied potentials. |
| Danaila and Benea et al., 2017 | •Ti10Zr • TiO₂-ZrO₂ | • Type: pin–on–disc tribometer • Counterbody: Al2O3 pin cylinder (Ø 7 mm) • Potentiostat: 3-electrode 1287 potentiostat | • Applied Load: 2 N and 5 N • Speed: 120 rpm • Duration/cycles: 5000 cycles | • Electrolyte solution: Fusayama - Mayer artificial saliva (pH 4.8) • Current: 200 mV vs. SHE • Time/cycles: 30 min, sliding and 30 min after | •OCP (V Ag/AgCl) • COF | TiO2–ZrO2 thin film electrochemical formed on Ti-10Zr alloy lead to an improvement of tribocorrosion resistance compared to non-anodized Ti-10Zr alloy. |
| Dimah et al., 2012 | •Ti-Grade 2 • Ti6Al4V • Ti6Al4V-ELI | • Type: ball-on-disk tribometer • Counterbody: Al2O3ball (Ø 6 mm) • Potentiostat: 3-electrode cell potentiostat Solartron 1286 | • Applied Load: 50 N • Speed: 60 rpm; 20 mm/s • Duration/cycles: intermittent sliding was applied with different time cycles • Contact stress: 950 MPa | • Electrolyte solution: PBS and PBS–BSA solutions • Current: 205 mV vs SHE • Time/cycles: 60 min sliding and 20 min after sliding was stopped • Surface area: 2.06 cm² | • OCP • Current evolution I (mA) • Wear volume mm³ • Wear tracks (SEM)*(Continues)* | Wear accelerated corrosion was twice in the case of the Ti-Grade 2. Wear coefficient increases when rest time between sliding cycles increases. BSA adsorbs on the metallic surface thus reducing the repassivation kinetics. |
| Table 1. Description of experimental studies in tribocorrosion focused on implant dentistry |
| Author (year) | **Biomaterial** | **Tribological test** | **Working parameters** | **Response variable** | **Main findings** |
| **Mechanical parameters** | **Corrosion parameters** |
| Fazel et al., 2015 | •Ti • Ti6Al4V • MAO/Ti • MAO/Ti6Al4V | • Type: tribometer • Counterbody: SiC ball (Ø 7 mm) • Potentiostat: 3-electrode EG&G Potentiostat model 263A | • Applied Load: 5 N • Frequency: 1 Hz • Duration/cycles: 1800 (untreated) or 2400 (MAO coated) cycles • Stroke distance: 5 mm | • Electrolyte solution: 0.9 wt.% NaCl • Temperature: 37 °C • Time/cycles: 1000 s before, 1800 or 2400 s during and 1200 s after the sliding • Surface area: 1 cm² | • OCP (mV) • Wear tracks (SEM) | The potential of untreated samples was dropped sharply to very low negative values. However, the lower wear volume loss was achieved for Ti6Al4V. |
| Figueiredo-Pina et al., 2015 | • Zirconia ball x Ti6Al4V plate • Ti6Al4V ball x zirconia plate. | • Type: pin-on-plate reciprocating (Nanosurf Easyscan 2) • Counterbody: Ti ball and Zr ball • Potentiostat: 3-electrode Gamry 600 | • Applied Load: 200 mN • Frequency: 1 Hz • Duration/cycles: 10 min • Contact stress: 150 MPa • Stroke distance: 1 mm | • Electrolyte solution: artificial saliva • Temperature: at room temperature • Current: 1 mV/s • Time/cycles: 10 min | • OCP (V) • Current density (A/cm2) | There are differences in tribocorrosion behavior between experimental configurations. |
| Golvano et al., 2015 | •cpTi4 35.0, 35.100, 35.1000; • Ti13Nb13Zr 35.0, 35.100, 35.1000. | • Type: ball-on-plate reciprocating tribometer • Counterbody: Al2O3ball (Ø 6 mm) • Potentiostat: 3-electrode Voltalab 40 | • Applied Load: 1 N • Frequency: 1 Hz • Duration/cycles: 60 min • Contact stress: 320 MPa (cpTi4) and 360 MPa (Ti13Nb13Zr) • Stroke distance: 2 mm | • Electrolyte solution: Fusayama Meyerartificial saliva (with NaF and differents pHs) • Temperature: 37 °C • Current: +244 mV/SHE • Time/cycles: 60 min before, 60 min sliding and 20 min after | • OCP (mV vs SCE) • COF • Wear tracks (SEM) • Wear volume (mm³/Nm) | There is a negative influence of the increase of fluoride concentration and the acidified artificial saliva on the material degradation. |
| Guinon Pina et al., 2016 | •cpTi • Ti-3Cu • Ti-7.1Cu • Ti-12Cu | • Type: ball on disk tribometer • Counterbody: Al2O3ball (Ø 6 mm) • Potentiostat: 3-electrode Solartron 1286 potentiostat | • Applied Load: 1, 5 and 10 N • Speed: 60 rpm, 19 mm/s • Duration/cycles: 1 h • Contact stress:369, 631, 796 MPa | • Electrolyte solution: artificial saliva (pH 6.6) • Temperature: 37 °C • Time/cycles: 1 h, 1 h during and 20 min after • Surface area: 2.56 cm² | • OCP E (V Ag/AgCl) • Wear tracks (SEM) • Wear volume ($10^{-3}$mm³) • Volume loss • Mass transfer (mm²) | Total material loss due to the wear and corrosion decreases with the increase in the Ti2Cu intermetallics, which also reduces wear volume. |
| Licausi et al., 2013a | •Ti6Al4V (cast) •Ti6Al4V (sintered by powder metallurgy) | • Type: Ball-on-disc tribometer •Counterbody: Al2O3ball (ø =6mm) • Potentiostat: 2-electrode electrochemical cell | • Applied Load: 5 N • Speed: 60 rpm • Frequency: 1 Hz • Duration/cycles: 1 h • Contact stress: 960 Mpa | • Electrolyte solution: Artificial saliva (with and without fluorides) •Temperature: 37°C • Surface exposed: 2.06cm² | • OCP (V) •Corrosion Current (mA) | Fluorides increase the wear accelerated corrosion at high concentrations (above 1000 ppm at pH 6.5). |
| Licausi et al., 2013b | •Ti6Al4V (cast) •Ti6Al4V (sintered by powder metallurgy) | • Type: Ball-on-disc tribometer •Counterbody: Al2O3ball (ø =6mm) • Potentiostat: 2-electrode electrochemical cell | • Applied Load: 5 N • Speed: 60 rpm • Frequency: 1 Hz • Duration/cycles: 1 h • Contact stress: 960 Mpa | • Electrolyte solution: Artificial saliva (with and without fluorides) •Temperature: 37°C • Surface exposed: 2.06cm² | • OCP (V) •Corrosion Current (mA) | Cast and sintered titanium alloys exhibit the same tribocorrosion mechanisms independently of the pH and wear damage is mainly due to the mechanical action. |
| Mardare et al., 2012 | • Ti6Al4V (grade V) | • Type: Uni-directional reciprocating tribometer •Counterbody: Al2O3ball (ø =10mm) • Potentiostat: 3-electrode electrochemical cell | • Applied Load: 1,2 and 5 N • Frequency: 1 Hz • Duration/cycles: 10 min/1000 cycles •Stroke distance: 200 µm | • Electrolyte solution: Fusayama-Mayer artificial saliva (pH 5) •Temperature: 23°C | • OCP (mV vs Ag/AgCl) • COF (µ) • Surface roughness (nm) | The restoration ability of Ti-6Al-4V alloy after the passive films damaged during fretting was observed when the fretting motion has ceased. A decrease in friction coefficient with gradually increasing load also was observed. |
| Marques et al., 2016 | •cpTi (untreated) • cpTi (MAO coating) • cpTi (SLA coating) | • Type: Uni-directional reciprocating tribometer (DUCOM-Material Characterization Systems, Evanston, IL, USA) •Counterbody: Al2O3ball (ø =3/8''mm) • Potentiostat: 3-electrode electrochemical cell (SP-240 Bio-Logic, LLC, Knoxville, TN, USA) | • Applied Load: 8,5 N • Frequency: 1 Hz • Duration/cycles: 2000 cycles •Stroke distance: 200 µm • Contact stress: 800 Mpa •Stroke distance: 3 mm | • Electrolyte solution: Artificial saliva (pH 6.5) •Temperature: 37°C | • OCP (V vs SCE) •Corrosion Current (mA/cm²) • COF (µ) • Total mass loss (µg) | The high amount of Ca and microstructure of the coating play an important role in enhancing the tribocorrosion resistance. |
| Mathew et al., 2012a | • cpTi alloy | • Type: Pin-on-ball tribo-system •Counterbody: Al2O3ball (ø =28 mm) • Potentiostat: 3-electrode electrochemical cell | • Applied Load: 20 N • Frequency: 1,2 Hz • Duration/cycles: 2000 cycles •Stroke distance: 200 µm • Contact stress: 372 Mpa •Stroke distance: 3 mm | • Electrolyte solution: Fusayamaand Meyer’s artificial saliva (pH:3, 6 and 9) •Temperature: 37°C | • OCP (V vs SCE) •EIS (KΩ.cm2) •Polarization curves (A/cm2) • Weight Loss (µm³)*(Continues)* | Titanium shows inferior performance in tribocorrosion at pH 6.0. |
| Table 1. Description of experimental studies in tribocorrosion focused on implant dentistry |
| Author (year) | **Biomaterial** | **Tribological test** | **Working parameters** | **Response variable** | **Main findings** |
| **Mechanical parameters** | **Corrosion parameters** |
| Mathew et al., 2012b | •cpTi • Ti6Al4V | • Type: Pin-on-ball tribo-system •Counterbody: Al2O3ball (ø = 28 mm) • Potentiostat: 3-electrode electrochemical cell | • Applied Load: 20 N • Frequency: 1,2 Hz • Duration/cycles: 2000 cycles •Stroke distance: 200 µm • Contact stress: 372 Mpa •Stroke distance: 3 mm | • Electrolyte solution: artificial saliva (pH 6.5 with 0.15, 15 and 150 μg/ml of LPS) •Temperature: 37°C • Surface exposed: 1.13 cm² | • OCP (V vs SCE) •EIS (KΩ.cm2) •Polarization curves (A/cm2) • COF (µ) • Total weight Loss (µm³) • Surface roughness (nm) • Wear tracks (SEM) | LPS negatively affected the corrosion/wear behavior of titanium. |
| Mindivan et al., 2016 | •Co-Cr alloys (cast and milled) | • Type: Ball-on-disc reciprocating tribometer •Counterbody: Al2O3ball (ø = 10 mm) • Potentiostat: 3-electrode electrochemical cell | • Applied Load: 5 N • Duration/cycles: 45 min •Stroke distance: 200 µm •Stroke distance: 1,7 cm/s | • Electrolyte solution: artificial saliva • Surface exposed: 2 cm² | • OCP (mV) • COF (µ) • Surface roughness (nm) • Wear tracks (SEM) | The tribocorrosion performance of milled Co-Cr alloy are satisfactory and this material seems to be suitable for application biomedical.  |
| Mindivan and Mindivan, 2018 | • Co-Cr alloys (Pulsed Plasma Nitriding) | • Type: Ball-on-disc reciprocating tribometer •Counterbody: Al2O3ball (ø =10mm) • Potentiostat: 3-electrode electrochemical cell | • Applied Load: 5 N • Duration/cycles: 45 min •Stroke distance: 200 µm • Speed: 1,7 cm/s | • Electrolyte solution: artificial saliva • Surface exposed: 2 cm² | • OCP (mV) • Current density (A/cm2) • COF (µ) • Wear tracks (SEM) | Pulsed plasma nitriding process affected the tribocorrosion behavior of cast CoCr alloy (lower COF, higher OCP, lower wear volume loss and lower amount of wear debris). |
| Oliveira et al., 2015 | •cpTi (grade II) •cpTi (MAO treatment) | • Type: Pin-on-disk reciprocating sliding tribometer (CETR-UMT 2) •Counterbody: Al2O3ball (ø =10 mm) • Potentiostat: 3-electrode electrochemical cell (Gamry Instruments potentiostat/galvanostat Reference 600) | • Applied Load: 1.5 N • Frequency: 2 Hz • Duration/cycles: 7256 cycles •Stroke distance: 10 mm | • Electrolyte solution: SBF solution •Temperature: 37°C • Surface exposed: 2 cm² | • OCP (V vs SCE) • Current density (A/cm2) • Surface roughness (µm) • Wear tracks (SEM) | The addition of magnesium was shown to support the formation of rutile which improves the tribocorrosion properties of the surfaces. |
| Pontes et al., 2016 | •Co-Cr alloy | • Type: Ball-on-platetribometer (CETR-UMT-2) •Counterbody: Al2O3ball (ø =10 mm) • Potentiostat: 3-electrode electrochemical cell (Gamry Instruments potentiostat/galvanostat Reference 600) | • Applied Load: 5 N • Duration/cycles: 45 min • Speed: 1,7 cm/s | • Electrolyte solution: Commercial mouthwashes alcohol-free and alcohol added in artificial saliva solutions •Temperature: 37°C • Surface exposed: 2 cm² | • OCP (V vs SCE) • COF • Corrosion current i (μΑ) • Wear track depth (μm) • Wear tracks (SEM) | Results suggest that the presence of mouthwashes did not affect negatively the corrosion and tribocorrosion behavior of Co-Cr dental alloy. |
| Richard et al., 2010 | •cpTi (untreated) • ZrO2  • Al2O3-13 wt.% TiO2 | • Type: Ball-on-platetribometer (E77 tribometer made by Phoenix Tribology Company, UK) •Counterbody: Al2O3ball (ø = 6mm) • Potentiostat: 3-electrode electrochemical cell (Gamry PC4/750 potentiostat - Gamry Instruments, USA) | • Applied Load: 10 N • Frequency: 5 Hz •Stroke distance: 15 mm | • Electrolyte solution: Hank’s solution •Temperature: 37°C  | • OCP (V vs SCE) • COF • Corrosion current i (μΑ) • Wear track depth (mm) • Wear tracks (SEM) | Results showed that corrosion resistance was appreciably higher for alumina–titania coating. |
| Sampaio et al., 2016b | •Ti6Al4V (veneering of PEEK) | • Type: Reciprocating ball-on-plate tribometer (Bruker-UMT-2,USA) • Counterbody: Al2O3balls (ø = 10 mm) • Potentiostat: 2-electrode electrochemical cell (Gamry600,USA) | • Applied Load: 30 N • Frequency: 1 Hz • Duration/cycles: 30 min • Stroke distance: 3 mm | • Electrolyte solution: Fusayama's artificial saliva •Temperature: 37°C •Surface exposed: 0.5 cm² • Time/cycles: 60 min | • OCP (mV vs Ref.) • COF (µ) • Material wear loss (mm³) | Under tribocorrosion conditions the PEEK veneer protected the Ti6Al4V substrate from corrosion and wear. |
| Sikora et al., 2018 | •TiZr • TiV | • Type: Linear reciprocating tribometer (DUCOM; Material Characterization Systems, Evanston, IL) • Counterbody: TiV and ZrO2 balls (ø = 3/8”) • Potentiostat: 3-electrode system (SP-240;Bio-Logic, LLC, Knoxville, TN) | • Applied Load: 8 N • Frequency: 2 Hz • Duration/cycles: 25.000 cycles • Stroke distance: 2 mm | • Electrolyte solution: Fusayama and Meyer’s artificial saliva (pH: 6.5) •Temperature: 37°C • Time/cycles: 60 min •Surface exposed: 0.5 cm² | • OCP (V) • COF (µ) • Wear volume loss (µm³) • Surface roughness. (nm) | The best performing group was Zr/Ti, and the worst performing group was Ti/Ti. |
| Silva et al., 2016 | •Ti6Al4V alloy (untreated) •Ti6Al4V alloy (laser remelting ) | • Type: A pin-on-disk tribometer (Homemade, Nova Friburgo, Brazil) • Counterbody: Al2O3 balls (ø = 4 mm) • Potentiostat: 3-electrode system (Advanced Measurement Technology Inc., Oak Ridge, TN, USA) | • Applied Load: 2 N • Speed: 75 rotations per minute • Frequency: 1.25 Hz • Contact stress: 410 MPa | • Electrolyte solution: NaCl 0.90 wt.% (pH: 6.5) •Temperature: 37°C • Time/cycles: 60 min | • OCP (V vs SCE) •EIS (KΩ.cm2) •Polarization curves (A/cm2) • COF (µ) • Wear volume loss (µm³) • Surface roughness(nm) •Tracks (AFM) | Initial rubbing reveals that laser-remelted Ti6Al4V samples present better tribocorrosion resistance (shallower track wear) than ordinary non-treated Ti6Al4V-BM samples.*(Continues)* |
| Table 1. Description of experimental studies in tribocorrosion focused on implant dentistry |
| Author (year) | **Biomaterial** | **Tribological test** | **Working parameters** | **Response variable** | **Main findings** |
| **Mechanical parameters** | **Corrosion parameters** |
| Sivakumar et al., 2011 | • Ti6Al4V alloy | • Type: fretting corrosion test assembly •Counterbody: Al2O3 balls (ø = 8 mm) • Potentiostat: ACM instruments (model: Gill AC) | • Applied Load: 3 N • Speed: 75 rotations per minute • Frequency: 5 Hz • Duration/cycles: 18.000 cycles • Stroke distance: 180 µm | • Electrolyte solution: artificial saliva (pH: 5.3) with (190, 570 and 1140ppm) and without fluoride •Temperature: 37°C • Time/cycles: 60 min | • OCP (mV vs SCE) • Material wear loss (mm³) • Wear tracks (SEM) | The study reveals that the fretting corrosion behavior of Ti–6Al–4V alloy in artificial saliva shows a strong dependence on the fluoride ion concentration. |
| Souza et al., 2010a | •cpTi (Grade II) | • Type: Modular Universal ScratchTester (MUST, Falex Tribology N.V., Belgium) •Counterbody: Al2O3 balls (ø = 5 mm) • Potentiostat: ACM instruments (model: Gill AC) | • Applied Load:100 and 200 mN • Frequency: 1 Hz • Stroke distance: 0.5 mm | • Electrolyte solution: artificial saliva (pH: 5.5) •Temperature: 37°C | • OCP (mV vs SCE) • COF (µ) • Wear tracks (SEM) | The pH-lowering promoted by microbial species, can lead to corrosion of Ti-based oral rehabilitation systems. |
| Souza et al., 2012 | •cpTi (Grade II) | • Type: tribometer (CETRUMT2 Multi specimenTestsystem) •Counterbody: Al2O3 balls (ø = 10 mm) • Potentiostat: PGZ100 model | • Applied Load: 3 N • Frequency:1 Hz • Stroke distance: 2 mm | • Electrolyte solution: artificial saliva with NaF (20,30, 227 and 12.300 ppm) (pH:5.5-6.5) •Temperature: 37°C | • OCP (V vs SCE) •EIS (KΩ.cm2) • COF (µ) • Weight loss (g/cm2) • Wear tracks (SEM) | The corrosion and wear resistance of the titanium oxide film formed at a Fˉ concentration of 12,300 ppm differ from the ones obtained up to 227ppm Fˉ. |
| Trino et al., 2018 | •cpTi (bio-functionalized coating) | • Type: Reciprocating ball-on-plate tribometer •Counterbody: Al2O3 ball (ø = 10 mm) • Potentiostat: 3-electrode corrosion cell | • Applied Load: 8.5 N • Frequency: 2 Hz • Duration/cycles: 3600 cycles (1800 s) • Stroke distance: 2 mm | • Electrolyte solution: PBS solution •Temperature: 37°C •Surface exposed: 1 cm² | • OCP (V vs SCE) •EIS (KΩ.cm2) • COF (µ) • Weight loss (g/cm2) • Wear tracks (Confocal) | Electrochemical and mechanical results indicated an increase in the corrosion and tribo-corrosion resistance of the functionalized material.  |
| Vieira et al., 2006 | •cpTi (Grade II) | • Type:Ball-on-disc tribometer •Counterbody: Al2O3ball (Ø 10 mm) • Potentiostat: 3-electrode corrosion cell system(Solartron electrochemical interface model 1287) | • Applied Load: 2 N • Frequency: 1 Hz • Duration/cycles: 5000 and 10.000 cycles • Stroke distance: 200 um | • Electrolyte solution: Artificial saliva without (pH: 5.5) and with citric acid (pH: 3.5) •Temperature: 23°C •Surface exposed: 1 cm² | • OCP (V vs Ag/AgCl) • COF (µ) •Corrosion Current (uA) • Wear volume loss (µm³) | The tribolayers become more stable after 7000 cycles in solutions containing citric acid or anodic inhibitor, as revealed by a lower coefficient of friction and a lower corrosion current. |
| Wang et al., 2018 | •Ti-30Zr alloy | • Type: ball-on-disk tribometer (TE66, UK) •Counterbody: ZrO2 ball (Ø25.4 mm) • Potentiostat: 3-electrode corrosion cell system (Gamry Interface 1000, USA) | • Applied Load: 1.0, 2.0, 3.0, 4.0 and 5.0 N • Speed: 150 rpm • Duration/cycles: 47.85 m | Not specified | • Polarization curves mA/cm² • Wear volume (mm³) • Wear tracks (SEM) | In Ti-30Zr, the material loss increased as the applied load increased.  |