Supplementary

In Vitro Simulation and In Vivo Assessment of Tooth Wear: A Meta-Analysis of In Vitro and Clinical Research

Despina Koletsi 1, Anna Iliadi 2, Theodore Eliades 1,* and George Eliades 2

1 Clinic of Orthodontics and Pediatric Dentistry, Center of Dental Medicine, University of Zurich, 8032 Zurich, Switzerland; d.koletsi@gmail.com
2 Department of Biomaterials, School of Dentistry, National and Kapodistrian University of Athens, 11527 Athens, Greece; annaeliades@gmail.com (A.I.); geliad@dent.uoa.gr (G.E.)
* Correspondence: Theodore.Eliades@zzm.uzh.ch

Table S1. Characteristics of included studies in alphabetical order (n = 27).

| Author          | Year | Origin    | Design | Sample size/enamel teeth type | Analysis Method | Groups under Comparison | Outcomes | Simulation Information/ follow-up |
|-----------------|------|-----------|--------|-------------------------------|----------------|-------------------------|----------|----------------------------------|
| Aldegheishem [1] | 2015 | Germany   | In vitro | 21 molars, lingual crown sections | laser scanner   | enamel (n = 7 each) vs different zirconia materials: 1. NanoZr (PNANOZR, Panasonic Healthcare), 2. Zeno (Zenostar, Wieland), 3. Cercon (Cercon HT, DeguDent). Subgroups (surface roughness): smooth (S) (Ra = 0.01 μm), moderate (M) (Ra = 0.1 μm), rough (R) (Ra = 1 μm) | 1.volumetric wear | 1,200,000 cycles thermomechanical fatigue, 98 N load, 1.6 Hz frequency (simulation of 5 years in vivo function) |
| Reference | Year | Country | Methodology | Sample Size | Surfaces Compared | Test Details | Result |
|-----------|------|---------|-------------|-------------|-------------------|--------------|--------|
| Al-Hiyasat [2] | 1997 | Jordan | In vitro | 30 mandibular premolars, 60 cusps | enamel (n = 10 each) vs. 1. glazed porcelain, 2. unglazed porcelain, polished porcelain | 1. mean wear depth | 5000, 15,000, 25,000 cycles of wear testing, 40 N load |
| Al-Hiyasat [3] | 1998 | Jordan | In vitro | 25 mandibular premolars, 50 cusps | enamel (n = 10 each) vs. 1. aluminous porcelain Vitadur Alpha, 2. bonded to metal porcelain Omega, 3. Low-fusing hydrothermal ceramic Duceram-LFC, 4. machinable ceramic Vita Mark II, 5. cast type IV gold | 1. mean wear | 5000, 15,000, 25,000 cycles of wear testing, under a load of 40 N |
| Al-Hiyasat [4] | 1999 | Jordan | In vitro | 15 mandibular premolars, 30 cusps | enamel (n = 10 each) vs. 1. conventional porcelain, 2. Low-fusing hydrothermal ceramic Duceram-LFC, 3. machinable ceramic Vita Mark II | 1. mean wear | 5000, 15,000, 25,000 cycles of wear testing, under a load of 40 N |
| Ashtiani [5] | 2019 | Iran | In vitro | 20 maxillary premolars | photography using a stereomicroscope (SF-100B, Lomo, Russia) | enamel (n = 10 each), vs. 1. feldspathic porcelain (VMK 95, Vita), 2. polymer-infiltrated ceramics (Vita Enamies) | 1. tooth wear | 120,000 cycles, chewing simulator, under a load of 5kg (~49 N) and 1.6 Hz frequency of antagonist movement |
| Bedini [6] | 2012 | Italy | In vitro | 25 molars | fatigue test by means of the servo-hydraulic 858 MiniBionix, testing machine (MTS) | enamel (n = 5 each), vs. 1. enamel, 2. hybrid microceramic composite, PEX composite, PFS composite | 1. volumetric fatigue difference, 2. surface fatigue difference | 1,000,000 cycles, compression load ranging from 34 to 340 N at a frequency of 6 Hz (i.e., this is a |
| Study             | Year   | Location       | Methodology        | Materials Description                                                                 | Simulation/Testing Conditions                                                                 |
|-------------------|--------|----------------|--------------------|--------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
| Chong [7]         | 2015   | Australia      | In vitro           | Enamel (n = 12 each), vs. 1. enamel (maxillary incosor), 2. Lab-polished zirconia, 3. Lab-polished and glazed zirconia, 4. clinically adjusted zirconia, 5. clinically adjusted and repolished zirconia | Enamel (n = 12 each), vs. 1. enamel (maxillary incosor), 2. Lab-polished zirconia, 3. Lab-polished and glazed zirconia, 4. clinically adjusted zirconia, 5. clinically adjusted and repolished zirconia |
| Esquivel-Upshaw   | 2018   | Florida, US    | clinical (RCT)     | Enamel (n = 30), vs. 1. Zirconia-reinforced lithium silicate glass ceramic (Vita Suprinity) | Enamel (n = 30), vs. 1. Zirconia-reinforced lithium silicate glass ceramic (Vita Suprinity) |
| Fathy [9]         | 2018   | Egypt          | In vitro           | Enamel opposed to steatite ball (n = 8) and compared to: 1. Feldspathic ceramic, 2. composite resin, 3. IPN resin, 4. PMMA resin networks, 5. TCR resin, | Enamel opposed to steatite ball (n = 8) and compared to: 1. Feldspathic ceramic, 2. composite resin, 3. IPN resin, 4. PMMA resin networks, 5. TCR resin, |
| Ghazal [10]       | 2008   | Germany        | In vitro           | Enamel (n = 12 each), vs. 1. enamel (maxillary incosor), 2. Lab-polished zirconia, 3. Lab-polished and glazed zirconia, 4. clinically adjusted zirconia, 5. clinically adjusted and repolished zirconia | Enamel (n = 12 each), vs. 1. enamel (maxillary incosor), 2. Lab-polished zirconia, 3. Lab-polished and glazed zirconia, 4. clinically adjusted zirconia, 5. clinically adjusted and repolished zirconia |

**Notes:**
- Simulation of 5 years in vivo aging
- Enamel (n = 12 each)
- 120,000 cycles, chewing simulator, under a load of 5 kg (~49 N) and 1.6 Hz frequency of antagonist movement
- 150,000 cycles, chewing simulator, under a load of 5 kg (~49 N) and 1.6 Hz frequency of antagonist movement
- 120,000, 240,000, 480,000, 840,000, and 1,200,000 cycles, chewing simulator (steatite ball), under a load of 5 kg (~49 N) and 1.6 Hz frequency
| Study Reference | Year | Country | Study Type | Number of Teeth | Methodology | Control | Treatment | Parameters | Results |
|-----------------|------|---------|------------|----------------|-------------|---------|-----------|------------|---------|
| Ghazal [11]     | 2009 | Germany | In vitro  | 24 maxillary first premolars | laser scanner | enamel opposed to zirconia ceramic balls of three different surface roughness (i.e., conventional, abraded with 50-μm alumina particles and 0.5 bar, and abraded with 50-μm alumina particles and 1 bar), compared to: 1. Nano-filled composite resin | 1. vertical substance loss, 2. volume loss | 300,000 cycles, mastication simulator, under a load of 5kg (~49 N) (zirconia ceramic ball) |
| Gundugolli [12] | 2018 | India   | In vitro  | 60 maxillary first premolars | cycling wear testing, chewing simulator | enamel vs. 1. unpolished unglazed layered zirconia, 2. polished unglazed layered zirconia, 3. polished glazed layered zirconia, 4. unpolished unglazed monolithic zirconia, 5. polished unglazed monolithic zirconia, 6. polished glazed monolithic zirconia | 1. vertical substance loss, 2. volume loss | 250,000 cycles, under load of 5 kg (~49 N), (i.e., this is a simulation of 1-year in vivo chewing) |
| Habib [13]      | 2019 | Saudi Arabia | In vitro | 32 premolars | 3D profilometer | enamel (8 each), vs. 1. monolithic zirconia, 2. lithium disilicate, 3. ceramic fused to metal, 4. composite resin | 1. vertical height loss, 2. weight | 240,000 cycles, under a load of 49 N, 0.8 Hz |
| Study | Year | Location | Type | Materials | Methodology | Comparison | Wear Parameters |
|-------|------|----------|------|-----------|-------------|------------|----------------|
| Janyavula [14] | 2013 | Alabama, US | In vitro | 8 mandibular molars | non contact surface profilometer | enamel vs. 1. polished zirconia, 2. glazed zirconia, 3. polished glazed zirconia, 4. veneering porcelain, 5. incisor enamel | 200,000 and 400,000 cycles, under a load of 10 N |
| Jung [15] | 2010 | Korea | In vitro | 60 premolars | 3D profilometer | enamel (n = 20 each) vs. 1. feldspathic porcelain, 2. zirconia polished, 3. zirconia glazed | 250,000 cycles, under load of 5 kg (~49 N), (i.e., this is a simulation of 1-year in vivo chewing) |
| Kim [16] | 2012 | Korea | In vitro | 100 maxillary and mandibular premolars | MTS 3D profiler | enamel (n = 10 each) vs. 600 and 1200 grit of groups: 1. monolithic zirconia Prettau, 2. monolithic zirconia Lava, 3. monolithic zirconia Rainbow, 4. lithium disilicate e.Max Press, 5. feldspathic porcelain Vita-Omega | 300,000 cycles, chewing simulator, under load of 5 kg (~49 N), (i.e., this is a simulation of 1-year in vivo chewing) |
| Lawson [17] | 2014 | Alabama, US | In vitro | 64 molars | Non-contact surface profilometer | enamel (n = 8 each), vs. 1. adjusted zirconia LAVA, 2. adjusted polished zirconia LAVA, 3. adjusted glazed zirconia LAVA, 4. adjusted lithium disilicate e.Max, 5. adjusted polished lithium disilicate e.Max, 6. adjusted glazed | 300,000 cycles, chewing simulator, under load of 10 N |
| Author | Year | Location | Study Type | Description | Comparison | Methodology | Results |
|--------|------|----------|------------|-------------|------------|-------------|---------|
| Lee [18] | 2014 | New Zealand | In vitro | 5 premolars/10 cusps | wear testing apparatus | enamel (n = 5 each), vs. 1. lithium disilicate glass ceramic e.Max, 2. type III gold | 1. friction coefficient for wear (μ) 1100 cycles, 9.8 N and 1.6 Hz |
| Mulay [19] | 2015 | India | In vitro | 60 maxillary first premolars | weight testing machine | enamel (n = 15 each), vs. 1. autoglazed ceramic, 2. overglazed ceramic, 3. ceramic polished with Shofu kit, 4. ceramic polished with DFS wheels | 1. percentage weight loss 5,000-10,000 cycles |
| Mundhe [20] | 2015 | India | clinical (RCT) | 10 patients, 30 teeth | 3D scanner for casts | enamel (10 each), vs. 1. antagonist enamel, 2. metal-ceramic, 3. monolithic zirconia | 1. wear 1 year evaluation |
| Olivera [21] | 2006 | Brazil | In vitro | 80 maxillary premolars | surface analyzer and computer program | enamel (n = 10 each), vs. 1. glazed ceramics, 2. polished ceramics of 5 commercial products (Empress 2, IPS, D-plus, D LFC, Symbio) | 1. total enamel wear 150,000 and 300,000 cycles, under load 20 N, chewing rate 1.3 Hz |
| Rupawala [22] | 2017 | India | In vitro | 60 maxillary first and second premolars | wear testing apparatus | enamel (n = 15 each), vs. 1. glazed zirconia, 2. polished unglazed zirconia, 3. porcelain fused to metal, 4. lithium disilicate | 1. loss of height 10,000 cycles, under load of 5 kg (50 N) |
| Study                      | Year | Country      | Design    | Sample Size | Methodology                                                                 | Materials Compared                                                                 | Key Results                                                                                     |
|----------------------------|------|--------------|-----------|-------------|-----------------------------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| Sripetchanond [23]         | 2014 | Thailand     | In vitro  | 24 molars   | profiler                                                                    | enamel (n = 6 each), vs. 1. monolithic zirconia, 2. lithium disilicate glass ceramic, 3. composite resin, 4. enamel of occlusal surface of third molar | 1. maximum depth of wear, 2. mean depth of wear 4800 cycles, under load of 25 N |
| Stawarczyk [24]            | 2013 | Switzerland  | In vitro  | 30 maxillary molars | 3D profilometer                                                          | enamel (n = 6 each), vs. 1. veneered zirconia, 2. glazed zirconia ceramic, 3. manually polished monolithic zirconia, 4. mechanically polished monolithic zirconia, 5. monolithic base alloy | 1. enamel wear 120,000, 240,000, 640,000, and 1,200,000 masticatory cycles |
| Stober [25]                | 2014 | Germany      | clinical  | 17 participants (mean age 43, SD 14) with corresponding/contralateral molar crowns | 3D laser scanner                                                                 | enamel (n = 17 each), vs. 1. monolithic zirconia, 2. enamel molar antagonist | 1. mean vertical loss, 2. maximum vertical loss 6-month evaluation |
| Yang [26]                  | 2019 | Korea        | invitro and clinical (RCT) | In vitro: 60 maxillary premolars; RCT: 30 patients requiring implant restoration of 1st/2nd molar | desktop scanner                                         | enamel (n = 15 each), vs. 1. polished Rainbow zirconia, 2. polished Katania zirconia | 1. vertical wear In vitro: 100,000 cycles, under load of 5 kg (~49 N), (i.e., this is a simulation of 6 months in vivo chewing); RCT: 6-month evaluation |
| Zheng [27]                 | 2016 | China        | In vitro  | 40 teeth/80 samples | laser scanning microscopy and 3D surface profilometer | enamel (n = 6 each) against silicon carbide ceramic ball, compared: 1. dried, 2. fresh enamel | 1. wear volume 5000, 50,000, 250,000, 550,000, 800,000, and 1,000,000 cycles under load of 20 N |
Table S2. Detailed assessment of the included randomized trials with the RoB 2.0 tool (supplement to Table 1).

| Domain                        | Reference | Esquivel-Upshaw 2018 | Mundhe 2015 | Yang 2014 |
|-------------------------------|-----------|----------------------|-------------|-----------|
| 1. Randomization process      |           |                      |             |           |
| 1.1                           | Y         | Y                    | Y           |           |
| 1.2                           | PY        | NI                   | NI          |           |
| 1.3                           | N         | PN                   | PN          |           |
| Judgement                     | Low       | Some concerns        | Some concerns | Some concerns |
| 2. Deviations from intended interventions |           |                      |             |           |
| 2.1                           | N         | NI                   | NI          |           |
| 2.2                           | PY        | NI                   | NI          |           |
| 2.3                           | PN        | PN                   | PN          |           |
| 2.4                           | NA        | NA                   | NA          |           |
| 2.5                           | NA        | NA                   | NA          |           |
| 2.6                           | PY        | PY                   | PY          |           |
| 2.7                           | NA        | NA                   | NA          |           |
| Judgement                     | Low       | Low                  | Low         | Low       |
| 3. Missing outcome data       |           |                      |             |           |
| 3.1                           | Y         | Y                    | Y           |           |
| 3.2                           | NA        | NA                   | NA          |           |
| 3.3                           | NA        | NA                   | NA          |           |
| 3.4                           | NA        | NA                   | NA          |           |
| Judgement                     | Low       | Low                  | Low         | Low       |
| 4. Measurement of the outcome |           |                      |             |           |
| 4.1                           | N         | N                    | N           |           |
| 4.2                           | PN        | N                    | N           |           |
| 4.3                           | NI        | NI                   | NI          |           |
| 4.4                           | PY        | PY                   | PY          |           |
| 4.5                           | PN        | PN                   | PN          |           |
| Judgement                     | Some concerns | Some concerns | Some concerns | Some concerns |
| 5. Selection of the reported result |           |                      |             |           |
| 5.1                           | NI        | NI                   | NI          |           |
| 5.2                           | PN        | PN                   | PN          |           |
| 5.3                           | PN        | PN                   | PN          |           |
| Judgement                     | Some concerns | Some concerns | Some concerns | Some concerns |
| Overall                       | Judgement | Some concerns        | Some concerns | Some concerns |

Materials 2019, 12, 3575; doi:10.3390/ma12213575
Y, yes; PY, probably yes; N, no; PN, probably no; NI, no information; NA, not applicable.
Table S3. Detailed assessment of the included non-randomized studies with the ROBINS-I tool (supplement to Table 2).

| Domain                        | Reference | Stober 2014 |
|-------------------------------|-----------|-------------|
|                               |           | 1.1 PY      |
|                               |           | 1.2 N       |
|                               |           | 1.3 N       |
|                               |           | 1.4 PY      |
| 1. Confounding                |           | 1.5 PY      |
|                               |           | 1.6 N       |
|                               |           | 1.7 NA      |
|                               |           | 1.8 NA      |
| Judgement                     | Moderate  |
|                               |           | 2.1 NI      |
|                               |           | 2.2 NA      |
| 2. Selection of participants  |           | 2.3 NA      |
| into the study                |           | 2.4 NI      |
|                               |           | 2.5 NA      |
| Judgement                     | NI        |
|                               | Low       |
|                               |           | 3.1 Y       |
| 3. Classification of          |           | 3.2 Y       |
| interventions                 |           | 3.3 PN      |
| Judgement                     | Low       |
|                               |           | 4.1 PN      |
|                               |           | 4.2 NA      |
| 4. Deviations from intended   |           | 4.3 NA      |
| interventions                 |           | 4.4 NA      |
|                               |           | 4.5 NA      |
|                               |           | 4.6 NA      |
| Judgement                     | Low       |
|                               |           | 5.1 PY      |
| 5. Missing data               |           | 5.2 N       |
|                               |           | 5.3 NI      |
|   | 5.4 | NA |
|---|-----|----|
|   | 5.5 | NA |
| Judgement | Low |

|   | 6.1 | PY |
|---|-----|----|
|   | 6.2 | NI |
| 6.3 | PY |
|   | 6.4 | PN |
| Judgement | Moderate |

|   | 7.1 | NI |
|---|-----|----|
|   | 7.2 | PN |
| 7.3 | PN |
| Judgement | Moderate |

### Overall

Judgement Moderate

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Y, yes; PY, probably yes; N, no; PN, probably no; NI, no information; NA, not applicable.
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