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SYSTEMATIC REVIEW

# Antagonist enamel wear of tooth-supported monolithic zirconia posterior crowns in vivo: A systematic review

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## ABSTRACT

**Statement of problem.** An assessment of the evidence for the antagonist enamel wear of tooth-supported monolithic zirconia posterior crowns is lacking.

**Purpose.** The purpose of this systematic review was to identify and summarize clinical studies related to the antagonist enamel wear of tooth-supported monolithic zirconia posterior crowns.

**Material and methods.** PubMed, Embase, and Cochrane library searches were performed and complemented by manual searches from database inception to December 25, 2017, for title and abstract analysis.

**Results.** Initially, 198 articles were obtained through database searches. Twenty-one articles were selected for full-text analysis, and 5 studies met the inclusion criteria. Because of the heterogeneity in design, surface treatment, measurement methods, and wear parameters, a meta-analysis was not possible. The selected studies were analyzed regarding the antagonist natural enamel wear of zirconia, measurement methods, and surface treatment. The results of the antagonist enamel wear varied widely, which made comparing them scientifically with absolute values difficult.

**Conclusions.** This review indicated that the antagonist enamel wear of zirconia was similar to or more than that of natural teeth but less than that of metal-ceramics. Additional properly designed, longer follow-up clinical trials with larger sample sizes are needed to evaluate the antagonist enamel wear of monolithic zirconia crowns in vivo. (J Prosthet Dent 2019;121:598-603)


Ceramic restorations have become increasingly popular because they are metal free and have excellent esthetics and biocompatibility.[1] However, veneered ceramic restorations have a high incidence of chipping and delamination, which are the main causes of failure.[2] The reasons for chipping and delamination include the mismatch of thermal coefficients between the zirconia framework and veneer and the fast cooling rate.[3] Although the incidence of chipping can be decreased by reducing the cooling rate of porcelain,[4] translucent monolithic zirconia restorations without any veneering have become more popular. However, monolithic zirconia restorations have high strength and hardness. Therefore, the abrasion between the zirconia and the opposing natural tooth caused by high hardness and surface roughness is a concern.[5-10]

Dental wear involves different factors and can lead to loss of occlusion height, poor esthetics, increased tooth sensitivity, reduced masticatory function, and temporomandibular joint dysfunction (TMD).[6,11,12] The mechanism of wear involves 3 processes: erosive wear is caused by dissolution of hard tissue by acidic substances; abrasive wear is the interaction of 3 materials including teeth and another material, such as food; and attrition is caused by tooth-to-tooth contact (2-material wear). The 3 processes rarely act alone but combine to contribute to tooth wear.[13,14]

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## Clinical Implications

A well-polished monolithic zirconia crown exhibited similar or more antagonist enamel wear than natural teeth but less than metal-ceramics. Therefore, a monolithic zirconia crown may be a better choice than metal-ceramics for posterior tooth-supported restorations if concerns about wear abrasion of opposing enamel exist.

Among the factors of enamel wear related to prosthetic materials, hardness and surface roughness have been implicated. Conventionally, higher hardness was believed to lead to more antagonist enamel wear.[11,12] Zirconia has higher surface hardness (approximately 13 GPa) than feldspathic ceramic (4.9 GPa) or enamel (3.14 to 3.72 GPa).[6,15] Hence, zirconia might be expected to cause more wear. However, studies have indicated that the antagonist enamel wear of zirconia was less than that of feldspathic ceramics or natural tooth[12,16,17] probably because its high fracture strength can maintain a smooth zirconia surface.[15] However, if the zirconia is left rough, it will likely cause antagonist enamel wear.[18]

As roughness affects zirconia and antagonist wear, surface treatment is important to decrease tooth wear.[19] Intraoral occlusal adjustments are often required to obtain an optimal occlusal contact, and any adjustment will increase the surface roughness. Glazing or polishing is a common technique to decrease roughness,[20,21] but different polishing systems can exhibit different degrees of roughness. Al-Haj Husain et al[22] reported that zirconia exhibited average roughness ranging between 0.13 and 1.11 μm after polishing with zirconia-polishing systems. Other studies reported lower values, ranging between 0.08 and 0.9 μm after polishing with different zirconia-polishing systems.[20,23,24] Higher values, between 2.12 and 3.10 μm, however were observed when zirconia was polished with a feldspathic porcelain-polishing system.[23] A suitable polishing technique should therefore be chosen for each zirconia system.[22-24] One study reported that 26% monoclinic phase was observed after grinding and 23% to 24% monoclinic phase after polishing.[20] However, Park et al[23] reported that the most monoclinic phase was 0.09% after polishing. Other studies showed that polishing processes did not cause phase transformations in the zirconia specimens.[22,25,26] In addition, polishing could enhance the flexural strength and fatigue strength of zirconia.[20,21] Yttria-stabilized zirconia polycrystal (Y-TZP) may undergo a toughening effect from the phase transformation, arresting crack propagation.[21,27]

Y-TZP has 2 special characteristics: transformation toughening and low-temperature degradation (LTD). Transformation toughening contributes to the high fracture strength of Y-TZP and is regarded as a self-healing mechanism.[28] When tensile stresses are generated at the tip of a crack, the tetragonal phase converts to the monoclinic phase with volumetric expansion and subsequent compressive stresses around the crack. This results in partial closure of the crack and prevents its further extension.[28] Therefore, transformation toughening may help the zirconia keep a smoother surface and results in decreased antagonist enamel wear. However, LTD would cause loss of strength, surface roughening, and microcracking. Specifically, with water penetration of the crystalline structure, the tetragonal phase could transform into the monoclinic phase with time.[29] This phenomenon has been widely reported in vitro[30] but only in a few in vivo studies. One clinical study indicated that LTD did indeed occur in the mouth at a rate comparable with the lifespan of dental restorations (approximately 15 years).[29] Zhao et al[31] reported that the electrolytes in artificial saliva did not have an additional effect on the LTD. However, LTD increased from the neutral to the alkaline environment and from the alkaline to the acidic environment.[32]

In vitro studies have shown that monolithic zirconia crowns cause less antagonist enamel wear than other ceramic or metal-ceramic restorations.[17,33] Moreover, polished zirconia might exhibit less enamel wear than glazed zirconia.[34-38] Nevertheless, intraoral wear is a complex phenomenon affected by physical, chemical, and biologic factors. The pattern of enamel wear is influenced by the restoration material, surface texture, acidic diet (or acid reflux), masticatory force, TMD, bruxism, dietary habits, and unilateral mastication habits.[6,8,11,15] Therefore, in vitro studies cannot fully simulate actual clinical enamel wear.

The clinical evaluation of enamel wear caused by monolithic zirconia has mostly been by using prospective studies and randomized controlled trials, but the authors are unaware of a systematic literature review. Therefore, this systematic review was conducted to determine the extent and characteristics of reported enamel wear caused by monolithic zirconia in vivo, measurement methods used, wear parameters, and surface treatment.[5-10]

## MATERIAL AND METHODS

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[39] Potentially relevant articles were electronically searched in PubMed, Embase, and the Cochrane library databases from database inception through December 25, 2017. The search strategy included combinations of the terms tooth wear, dental enamel, antagonist, occlusal wear, enamel wear, zirconia, zirconi, and zirconium dioxide, either as

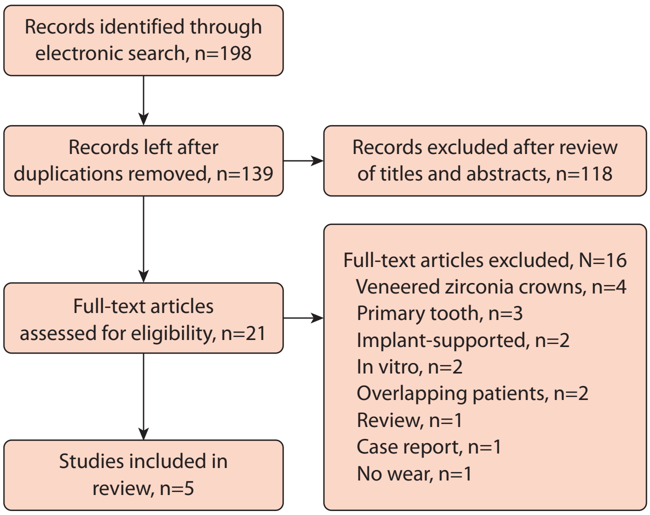


**Figure 1.** Flow diagram showing selection process.

keywords or Medical Subject Heading (MeSH) terms. The references of the retrieved articles were manually searched to identify relevant articles, then titles and abstracts were read for possible full review and inclusion. Full texts were screened and selected according to the inclusion criteria by 2 reviewers (M.G., H.C.) independently. Disagreements were resolved by discussion, and a third reviewer (J.K.) performed an independent review in case of disagreement. Whenever studies contained overlapping participants, the studies with the larger sample size, longer follow-up time, and more comprehensive data were included.

This systematic review was based on in vivo prospective clinical trials and randomized controlled trials. The inclusion criteria were human in vivo studies, studies on antagonist tooth enamel wear caused by Y-TZP crowns, and publications appearing in the English dental literature with mean follow-up time $\geq$6 months. The exclusion criteria were case reports, veneered zirconia crowns, participants with bruxism, ceramic crowns supported by implants or primary teeth, meta-analyses, and systematic reviews.

Details including the name of the first author, study design, number of participants, age and sex, number of crowns, position of crowns, zirconia system, control, follow-up, surface treatment, measurement methods, and quantity of wear were extracted. Because of the differences in measurement methods and surface treatment among the studies, data were found to be inappropriate for meta-analysis. Therefore, a qualitative synthesis of all outcomes was performed, and the analysis was presented as a systematic review.

## RESULTS

A total of 198 articles were initially retrieved by a literature search (Fig. 1), of which 59 articles were excluded because of duplication. After titles and abstracts had been reviewed, another 118 articles were excluded. Ultimately, 5 articles were included by assessing the full text according to the inclusion criteria.

The articles were published between 2015 and 2017. All 5 studies[6-10] were prospective studies, and 2 were randomized controlled trials.[6,7] Seventy-four participants aged between 18 and 73 years who needed tooth-supported complete-coverage posterior crowns with no TMD or parafunctional habits were involved. All the monolithic zirconia crowns were Y-TZP, and the follow-up time was 12 to 24 months. Enamel was selected as the control in 2 studies.[7,10] Enamel and metal-ceramics were designated as the controls in 1 study.[6] However, no controls were used in 2 other studies[8,9] (Table 1).

Polished zirconia crowns without glazing were involved in 4 studies[6-9]; however, the zirconia crowns were glazed after polishing in another study.[10] All the zirconia crowns were polished after occlusion adjustments (Table 2).

Indirect measurement methods were used in 4 studies.[6,7,9,10] Polyvinyl siloxane impressions were made at different times, and casts were poured with different replication materials. The casts were then scanned using a 3D scanner with different accuracies of 5 μm to 20 μm, and the data from the 3D scanner were analyzed with different thresholds (Table 2).

However, a direct measurement method was conducted by Hartkamp et al.[8] The teeth were air-dried after cleaning and scanned using an intraoral scanner after a thin layer of powder was applied to the teeth surface. The data were exported to an inspection software program for analysis (Table 2).

Antagonist enamel wear of zirconia was determined as loss of height or loss of volume. The controls were enamel or metal-ceramics. Mundhe et al[6] found that antagonist enamel wear of zirconia was less than that of metal-ceramics but more than that of natural tooth. Stober et al[10] also found that antagonist enamel wear of zirconia was more than that of natural tooth. However, Esquivel-Upshaw et al[7] found that antagonist enamel wear of zirconia was less than that of metal-ceramics and enamel at 6 months but more at 12 months. The absolute value of antagonist enamel wear of zirconia varied among different studies.[6-10]

The wear increased over time, but the rate of antagonist enamel wear decreased with time.[7,8,10] Antagonist enamel wear of zirconia was more than the wear of monolithic zirconia crowns.[7,10] The wear of molars was more than that of premolars[6] (Table 3).

## DISCUSSION

The antagonist enamel wear of zirconia was greater than that of the natural tooth, but less than that of

**Table 1.** Study and participant characteristics of reviewed studies

| Studies | Study Design | Patients Number | Age (y) | Crowns Number | Position of Crowns | Zirconia System | Control | Follow-up (mo) |
|---|---|---|---|---|---|---|---|---|
| Mundhe et al[6] | RCT | 10 (NA) | 18-35 | NA | Premolars and molars | Lava; 3M ESPE | Enamel vs enamel; enamel vs metal-ceramics | 12 mo |
| Stober et al[10] | Prospective | 20 (10 M and 10 W) | 21-73 | NA | Molars | Zenostar; Wieland Dental | Enamel vs enamel | 24 mo |
| Esquivel-Upshaw et al[7] | RCT | 25 (5 M and 20 W) | >21 | 30 | Premolars and molars | Lava; 3M ESPE | Enamel vs enamel | 12 mo |
| Lohbauer and Reich[9] | Prospective | 10 (7 M and 3 W) | 45.2 ±11.9 | 14 | Premolars and molars | Lava Plus; 3M ESPE | No | 24 mo |
| Hartkamp et al[8] | Prospective | 9 (5 M and 4 W) | NA | 13 | Premolars and molars | Lava Plus; 3M ESPE | No | 24 mo |

RCT, randomized controlled trials; NA, not available; M, men; W, women.

metal-ceramics.[6,10] However, Esquivel-Upshaw et al[7] reported that the antagonist enamel wear of zirconia was less than that of metal-ceramics and enamel at 6 months but more at 12 months. In contrast, many in vitro studies have shown that zirconia causes less antagonist enamel wear than enamel and metal-ceramics[17,34] or comparable wear.[40] Moreover, wear increased over time, but the rate of antagonist enamel wear decreased with time.[5,7-10] A possible reason is that running-in wear takes over after the placement of restorations, and stable wear takes over after 2 years.[41] The cusps become shorter and flatter, but the base surface area becomes larger with time.[42] As the area and number of wear facets increase, the occlusal force per unit of surface area lessens, and the vertical height loss decreases. In addition, higher wear rates may also be self-limiting because of the reduction in occlusal stress.[43] The wear of molars was reported to be more than that of premolars because molars have greater occlusal force.[6]

The degree of wear varied widely among different studies because of biologic differences among individuals such as age, sex, diet, occlusal force, position of restorations, and bruxism.[41] Other factors that could lead to differences in the degree of antagonist enamel wear of monolithic zirconia crowns are measurement methods, surface treatment, and wear parameters.

The direct measurement method is the intraoral 3D scanning of teeth.[8] The advantages of the intraoral 3D scanning method are improved accuracy and simplification of steps, whereas the disadvantage is that error might be increased because of powdering the teeth.[11,44] The powder thickness is 20 to 40 μm.[45] Theoretically, the powder thickness could vary between operators and reduce accuracy, but the software of the intraoral scanner is capable of taking an average thickness into account.[46] Powder-free intraoral scanners have been developed which eliminate the potential inaccuracy caused by powder.

The indirect technique of evaluating tooth wear involves measuring cast replicates and was used by Mundhe et al and others.[6,7,9,10] Although this method is accurate and can quantify tooth wear, replication of the tooth surface and repositioning of the 3D images might decrease accuracy.[7,11,47] Furthermore, different replication materials and the accuracy of measurement systems make it difficult to compare the absolute value of wear found in different studies. Therefore, comparing the difference in the antagonist enamel wear between zirconia and natural tooth is recommended.[5] Nevertheless, only some of the reviewed studies used enamel controls.[6,7,10]

**Table 2.** Surface treatment and measurement methods of reviewed studies

| Studies | Surface Treatment | Measurement Methods |
|---|---|---|
| Mundhe et al[6] | Zirconia: polish (no glazing); metal-ceramics: glaze | Polyvinyl siloxane impressions before treatment and 1 year after adhesion<br>Casts: stone<br>Scanned using a 3D white light scanner (Breuckmann) (precision: ±9 μm)<br>Wear at occlusal areas |
| Stober et al[10] | Glaze after polish during manufacture of crowns; polish after occlusal adjustment | Polyvinyl siloxane impressions at baseline and at 6, 12, and 24 mo<br>Cast: type IV dental stone<br>Scanned using a 3D laser scanner (Willytec)<br>Wear of occlusal contact areas<br>Accuracy: 10 μm |
| Esquivel-Upshaw et al[7] | Zirconia: polish (no glazing); metal-ceramics: polish (no glazing) | Polyvinyl siloxane impressions at baseline and at 6 and 12 mo after adhesion<br>Cast: white gypsum material<br>Scanned using a 3D laser scanner (Straumann)<br>Wear of occlusal contact areas<br>Accuracy: 20 μm |
| Lohbauer and Reich[9] | Zirconia: polish (no glazing) | A-silicone Flexitime impressions at baseline and 24 mo after adhesion<br>Cast: epoxy resin material<br>Scanned using 3D high-resolution noncontact profilometer (cyberTECHNOLOGIES) (lateral step size of 5 μm)<br>Wear of regions-of-interest |
| Hartkamp et al[8] | Zirconia: polish (no glazing) | Intraoral digital scan at baseline and after 12 and 24 mo<br>Wear at occlusal areas<br>Threshold: 30 μm |

Mundhe et al[6] and other researchers[7-9] only measured the antagonist enamel wear of polished zirconia without glazing. Stober et al[10] evaluated the antagonist enamel wear of glazed zirconia in vivo but lacked a polished zirconia control. In vitro studies reported that glazed zirconia showed more tooth wear than polished unglazed zirconia.[34-38] Polished then glazed zirconia demonstrated slightly less antagonist enamel

**Table 3.** Wear results of crowns and opposing enamel obtained in reviewed studies

| | | Occlusal Wear of Crowns | | Occlusal Wear of Antagonist Enamel | | | Difference Between Antagonist Enamel Wear of Ceramics and Natural Tooth* | |
|---|---|---|---|---|---|---|---|---|
| Studies | Wear Parameter | Zirconia | Metal-ceramics | Natural Tooth | Zirconia | Metal-ceramics | Zirconia | Metal-ceramics |
| Mundhe et al[6] | Wear of premolar (μm) (mean wear; 12 mo) | – | – | 17.3 | 42.10 | 69.20 | – | – |
| | Wear of molar (μm) (mean wear; 12 mo) | – | – | 35.10 | 127.00 | 179.70 | – | – |
| Stober et al[10] | Mean vertical loss (μm) (24 mo) | 14 ±5 | – | 26 ±13 and 19 ±9 | 46 ±30 | – | – | – |
| | Maximum vertical loss (μm); (24 mo) | 60 ±11 | – | 115 ±60 and 75 ±29 | 151 ±77 | – | – | – |
| Esquivel-Upshaw et al[7] | Maximum wear (μm) (6 mo) | 38.4 | 30.9 | – | 51.9 | 64.4 | -9.9 | 2.4 |
| | Maximum wear (μm) (12 mo) | 46.1 | 49.5 | – | 70.3 | 63 | 9.2 | -23.4 |
| Lohbauer and Reich[9] | Volume loss ($mm^3$) (24 mo) | – | – | – | 0.361 ±0.485 | – | – | – |
| | Maximum vertical loss (mm) (24 mo) | – | – | – | 0.204 ±0.067 | – | – | – |
| Hartkamp et al[8] | Maximum vertical loss (μm) (12 mo) | – | – | – | 87 ±41 | – | – | – |
| | Maximum vertical loss (μm) (24 mo) | – | – | – | 115 ±71 | – | – | – |

*Negative number indicates more control wear than antagonist wear and vice versa.

wear than glazed zirconia alone.[38] Overall, polished zirconia is believed to cause less antagonist tooth wear than glazed zirconia because thin glaze layers will become worn within the first 6 months after insertion of the restorations even without any preceding occlusal adjustment[48]; this exposes the rough surface and increases the possibility of wear.[38] In addition, particles from the glaze may act as third-body abrasives.[38] The surface roughness of polished zirconia could be less than 0.2 μm, which is comparable with glazed zirconia.[20] Therefore, polishing is recommended to prevent antagonist enamel wear and maintain the structural strength of zirconia.[18,49]

Volume is an obvious wear parameter choice because wear is defined as the volume loss of tooth tissue.[11] In addition, the volume of wear increases proportionally with time[43,50,51] because there is a proportional increase in the base surface area related to a proportional decrease in the vertical height.[41] However, height and area of loss are not good parameters because they are affected by time and occlusion.[11,52] Most of the included articles chose height loss as the wear parameter, which increased the discreteness of the wear value and decreased the reliability of the results.

## CONCLUSIONS

Based on the findings of this systematic review, the following conclusions were drawn:

1. Well-polished monolithic zirconia exhibited similar or more antagonist enamel wear than natural teeth but less than metal-ceramics, in vivo.
2. Larger sample sizes, longer observation times, and clinical studies that adopt uniform measurement methods to compare the antagonist enamel wear of glazed and polished zirconia with that of natural enamel are required.

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