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Review

Influence of Different Treatments and Conditions on Optical Properties of Monolithic Zirconia: A Systematic Review

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Abstract: The present systematic review aimed to evaluate the influence of different treatments and conditions on the optical properties of monolithic zirconia. An electronic search was performed using the following databases: PubMed (National Library of Medicine, Bethesda, MD, USA), Web of Science (Clarivate, London, UK), Scopus (Elsevier, Amsterdam, Netherlands), Google Scholar (Google, Mountain View, CA, USA), and Embase (Elsevier, Amsterdam, Netherlands), with no restrictions on publication year and language. Based on the PICO format, the primary research question of this review was: "What is the impact of different treatments and conditions on the optical properties of monolithic zirconia?" From 145 relevant articles, 12 studies were chosen for systematic review (qualitative synthesis). A modified version of the "Guidelines for Reporting Pre-Clinical In-Vitro Studies on Dental Materials" was used to assess the overall quality of the included studies and any bias within them. The included studies assessed the optical properties (such as color stability, translucency, and surface gloss) of monolithic zirconia and other relevant ceramic materials using different treatments and conditions including aging (i.e., artificial, simulated, chemical, and hydrothermal), grinding/occlusal adjustment, glazing/external staining, toothbrushing, bleaching, and artificial gastric acid exposure. All the included studies (100%) reported a significant decrease ($p < 0.05$) in the optical properties of monolithic zirconia samples as compared to those of other relevant ceramic materials. Overall, different treatments and conditions had a negative impact on the optical properties of monolithic zirconia. In conclusion, the optical features assessed for monolithic zirconia, such as color stability, translucency, and surface gloss, appeared to be significantly compromised by different treatments and conditions including aging, grinding/occlusal adjustment, glazing/external staining, toothbrushing, bleaching, and artificial gastric acid exposure. However, the change was clinically not perceivable in 25% ($n = 3/12$) of the included studies. Due to the heterogenic parameters in the included studies, it is recommended to perform future studies using standardized conditions with different stains of zirconia over an extended duration to obtain conclusive evidence.

Keywords: monolithic ceramics; zirconia; color stability; esthetics; aging

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1. Introduction

Zirconia-based ceramics have been extensively used in restorative dentistry owing to their remarkable biocompatibility [1] as well as their tribological [2] and mechanical features [3–5]. Nonetheless, due to the opacity of zirconia, the design is required to be veneered with feldspathic ceramics to achieve acceptable outcomes. This bi-layered system of the core–ceramic design amalgamates the esthetics of the ceramic with the strength of zirconia [6,7].

However, veneered-zirconia restorations have shown increased clinical chipping rates of >30% [8–10], mandating a more invasive tooth preparation, and the fabrication procedure is more intricate. These clinical complications led to the development of monolithic zirconia with a modified microstructure possessing greater translucency and the incorporation of characterization pigments [11–13]. Compared to traditional metal-ceramic restorations and bi-layered zirconia crowns, monolithic zirconia possesses the benefit of reduced ceramic fracture rates [14]. Additionally, monolithic zirconia possesses remarkable translucency; furthermore, monolithic zirconia is esthetic owing to the lack of metal exposure at the margin of the restoration, even in the case of gingival recession of the abutment tooth [15,16]. Therefore, monolithic zirconia offers numerous benefits as an esthetic restorative dental material, making it the material of choice in the posterior region of the oral cavity due to its sufficient mechanical strength and toughness as well as tooth color [17–19].

Monolithic restorations, nevertheless, may pose challenges regarding esthetic shade matching and color stability [20–23]. It has been reported that the translucency of monolithic zirconia restoration can be affected by extrinsic (i.e., clinical and laboratory factors) and intrinsic (i.e., material processing and microstructural features) factors [24]. The clinician cannot manipulate the intrinsic factors; however, extrinsic factors can be manipulated by the clinician. Clinical factors, including low-temperature degradation [25], cement color [26], dental background [27], the utility of monolithic zirconia ceramics as dental implant abutments [28], surface finishing procedures [29], the color of monolithic zirconia ceramics [30], cementation type [31], and thickness [31], which lie in the category of extrinsic determinants should also be considered while assessing the translucency of monolithic zirconia ceramics.

Initially, the color of a monolithic zirconia dental restoration is influenced by the optical features and the original shade of zirconia ceramics is determined by the fabrication method. Several laboratory methods used for fabrication might affect the color. Clinical determinants, including the properties of zirconia restoration, cement, and dental background, might influence the resulting color. Shade reproduction of monolithic zirconia might be influenced during the long procedure from the fabrication of zirconia ceramics to the delivery of the restoration. Hence, the final color of the restoration might be the consequence of the impacts of elements such as clinical factors, laboratory methods, and fabrication procedures [16,32]. While the desired esthetic properties of zirconia dental restorations can be modulated by these factors, color matching must also be obtained utilizing appropriate and consistent light sources [15].

The durability of monolithic zirconia is a concern when the material is exposed to several challenges in the oral cavity during clinical service. These challenges include aging, grinding/occlusal adjustment, toothbrushing, and dental procedures such as bleaching [33–35]. According to Alghazzawi [36], most zirconia brands have lower L*, greater a*, and greater b* with increased aging, which corresponds, visually, to a darker, redder, and more yellow appearance. Aging also increased the contrast ratio, decreased the translucency parameter, and decreased the opalescence parameter. To our knowledge, no study has been performed so far to assess the influence of different treatments and conditions on the optical properties of monolithic zirconia as compared to other relevant ceramic materials. In addition, the durability of monolithic zirconia shade and color-matching is critical in restoration clinical maintenance, complications, failure, and replacement. Hence, the present systematic review aimed to evaluate the influence of different treatments and conditions on the optical properties of monolithic zirconia.

2. Materials and Methods

2.1. Protocol and Registration

The current systematic review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [37]. The protocol of this study has been registered in the Open Science Framework (OSF) Registries (https://doi.org/10.17605/OSF.IO/BRVT4).

2.2. Focused Question

For preparing and structuring the present systematic review, the focused question was formulated using the PICO format as follows [38]: Population: monolithic zirconia specimens (i.e., bars or plates); Intervention: monolithic aged zirconia; Comparison: non-aged zirconia ceramics; Outcome: effect of different treatments and conditions on optical properties of monolithic zirconia. Hence, the primary research question of this review is: “What is the impact of different treatments and conditions on the optical properties of monolithic zirconia?”

2.3. Information Sources and Search Strategy

With the help of a senior librarian specialized in health sciences database searches, an electronic search was undertaken using the following databases: PubMed (MEDLINE), Clarivate Analytics’ Web of Science, Elsevier’s Scopus, Google Scholar, and Embase, without no restrictions on publication year and language. The following search terms were used alone or in combination: “ceramic”, “dental ceramic”, “monolithic ceramic”, “stained ceramic”, “ceramic stain”, “color”, “color stability”, “gloss”, “surface hardness”, “surface roughness”, “ageing”, “optical”, “translucency”, “translucent”, “crystalline”, “hydrothermal”, “zirconia”, “monolithic zirconia”, “zirconium”, “zirconium oxide”, “Y-TZP”, “yttria-partially stabilized zirconia”, “yttria stabilized polycrystalline tetragonal zirconia”, “yttria-stabilized tetragonal zirconia”, “all-ceramic”, “light scattering”, and “light transmission”, either as Medical Subject Heading (MeSH, National Library of Medicine, Bethesda, MD, USA) terms or keywords. These terms were utilized with Boolean operators “OR”, “AND”, and “NOT”. Reference lists of the selected studies were subjected to thorough searches to identify potentially relevant studies. The cross-checking of the retrieved articles was performed to identify and remove duplicate articles, and the eligibility criteria (as determined by the PICO format) were applied to search for the studies.

2.4. Article Selection Procedure

The selection of articles was performed in the following three phases:

An independent investigator (T.A.) screened titles and abstracts following the eligibility criteria. In case of ambiguity regarding any studies, a full-text assessment of the articles was performed.

Full-text assessment of all possible and included studies chosen from phase 1 was performed (T.A.).

The bibliographies of all studies chosen in phase 2 were assessed by independent investigator (T.A.) together, and full texts of potentially eligible articles were evaluated.

2.5. Data Extraction Process

Microsoft Excel was used for the data collection procedure and a standardized data extraction table was employed: (i) study details such as author, year, and country of publication; (ii) material composition; (iii) study groups; (iv) color assessment instruments; (v) study sample size; (vi) cleaning medium; (vii) specimen treatments; (viii) study outcomes; and (ix) general outcomes.

2.6. Quality Assessment

A modified version of the “Guidelines for Reporting Pre-Clinical In-Vitro Studies on Dental Materials” formulated by Faggion [39] was used to assess the overall quality of the included studies and any bias within them. In brief, the following items were evaluated in the individual included studies: (i) adequate abstract; (ii) background [methods]; (iii) objectives [methods]; (iv) intervention [methods]; (v) outcomes [methods]; (vi) sample size [methods]; (vii) sequence generation [methods]; (viii) allocation concealment procedure [methods]; (ix) implementation [methods]; (x) blinding [methods]; (xi) statistical methods [methods]; (xii) outcomes and estimation [results]; (xiii) limitations [discussion]; (xiv) funding status [other information]; and (xv) accessibility of the full-trial protocol [other information]. Hence, a 15-point checklist was employed for grading the individual study. Each study was given an overall quality score of high (11–15), moderate (6–10), or low (0–5) [39].

3. Results

3.1. Study Selection

In total, 145 studies were initially retrieved via the literature search, from which 47 articles were excluded as duplicates. Manual searches of the reference lists of the included studies did not identify any additional studies. After reviewing the titles and abstracts, 86 more studies were excluded for not satisfying PICO. Finally, 12 studies were included by evaluating the full text as per the eligibility criteria [40–51]. Figure 1 depicts the PRISMA flow chart of the article selection procedure.

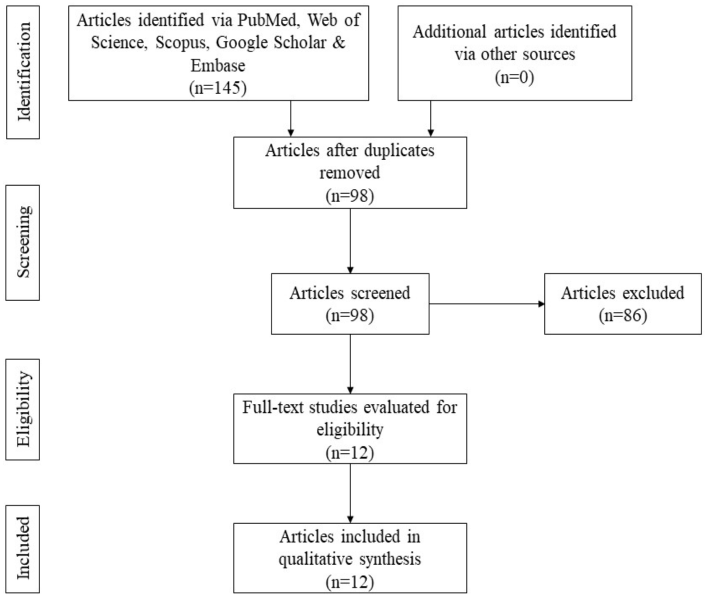

Figure 1. PRISMA flowchart of the article search strategy.

3.2. Primary Characteristics of Included Studies

Table 1 depicts the primary characteristics of the included 12 studies. The majority of the studies were conducted in Europe (*n* = 6) [40–42,44,48,51], followed by Asia (*n* = 5) [43,45,46,49,50] and Africa (*n* = 1) [47]. The cumulative sample size of the included studies was 959 ranging between 32 [43,45] and 210 [41]. Most of the studies (7/12; ~58%) used distilled water as the specimen cleaning medium [40,44–47,50,51], followed by alcohol (including 96% ethanol, 99% isopropanol, and 70% alcohol solution) in three studies (25%) [41,43,48], while two studies did not report any sample cleaning medium used [42,49]. The composition of the utilized material(s) was mentioned by 9 studies, however, three studies failed to report it [43,46,47]. In terms of the color assessment procedure, most of the studies used the CIELAB color system using a spectrophotometer. One study utilized a software program (i.e., UV Win-LabTM 2.8; PerkinElmer, Waltham, MA, USA) with a spectrophotometer [41], while another study employed a vita classical color scale used with a spectroradiometer [42].

3.3. Optical Properties Outcomes

The included studies assessed the influence of different treatments and conditions on the optical properties (such as color stability, translucency, and surface gloss) of monolithic zirconia and other relevant ceramic materials. Table 2 depicts the impact of different parameters on the optical properties of monolithic zirconia. These parameters include: (a) aging such as artificial [40], simulated [51], chemical [47], and hydrothermal [41]; (b) grinding/occlusal adjustment [42,48]; (c) glazing/external staining [43]; (d) tooth brushing [44,46,49,50]; (e) bleaching [45]; and (f) artificial gastric acid exposure [46].

Table 1. Primary characteristics of the 12 included studies.

Study	Sample Cleaning Medium	Study Group and Sample Size	Material Composition	Optical Properties Assessed	Color Assessment Method
(Kurt et al., 2019) [40] Turkey	Distilled water	• ***MZR (Zirkonzahn Prettau [ZZ],*** Atlanta, GA, USA) ✓ G: Glazing (*n* = 9) ✓ R: Rubber polishing system (*n* = 9) ✓ P: Rubber polishing system followed by polishing paste (*n* = 9) • ***Lithium disilicate glass-ceramic (IPS e.max Press [IPS])*** ✓ G: Glazing (*n* = 9) ✓ R: Rubber polishing system (*n* = 9) ✓ P: Rubber polishing system followed by polishing paste (*n* = 9)	***ZZ:*** ZrO_2 (92.27); Y_2O_3 (4–6); Al_2O_3 (<1); SiO_2 (0.02); Fe_2O_3 (0.01); Na_2O (0.04) ***IPS:*** SiO_2 (57–80); Li_2O (11–19); K_2O (0–13); P_2O_5 (0–11); ZrO_2 (0–8); ZnO (0–8); other oxides and ceramic pigments (0–10)	Color stability Translucency	• CIELAB color scale under a standard illuminant D65 (MASTER • TL-D Super 80 18 W/865 1 SL; Philips, Amsterdam, Netherlands) • Spectrophotometer (VITA • Easyshade Advance 4.0; VITA • Zahnfabrik, Bad Säckingen, Germany)
(Lümkemann et al., 2021) [41] Germany	96% ethanol	• Ceramill zi (3Y-$TZP_{0.25}$) (*n* = 30) • Ceramill Zolid (3Y-$TZP_{0.05}$) (*n* = 30) • Ceramill Zolid fx (5Y-TZP) (*n* = 30) • Ceramill Zolid ht+ (4Y-TZP) (*n* = 30) • Ceramill Zolid ht+ (4Y-TZP_{speed}) (*n* = 30) • Ceramill Zolid ht+ preshades A4 ($_{pre}$4Y-TZP_{speed}) (*n* = 30) • IPS e.max Press HT A4 ($LiSi_2$) (*n* = 30)	***3Y-TZP*$_{0.25}$**: $ZrO_2 + HfO_2 + Y_2O_3$ (>99.0); Y_2O_3 (4.5–5.6); HfO_2 (<0.5); Al_2O_3 (<0.5); other oxides (<0.5) ***3Y-TZP*$_{0.05}$**: $ZrO_2 + HfO_2 + Y_2O_3$ (≥99.0); Y_2O_3 (4.5–5.6); HfO_2 (≤5); Al_2O_3 (≤0.5); other oxides (≤1) ***5Y-TZP:*** $ZrO_2 + HfO_2 + Y_2O_3$ (>99.0); Y_2O_3 (9.15–9.55); HfO_2 (≤5); Al_2O_3 (≤0.5); other oxides (≤1) ***4Y-TZP 4Y-TZP*$_{speed}$**: $ZrO_2 + HfO_2 + Y_2O_3$ (≥99.0); Y_2O_3 (6.7–7.0); HfO_2 (≤5); Al_2O_3 (≤0.5); other oxides (≤1) **$_{pre}$*4Y-TZP*$_{speed}$**: $ZrO_2 + HfO_2 + Y_2O_3$ (≥99); Y_2O_3 (6.7–7.2); HfO_2 (≤5); Al_2O_3 (≤0.5); other oxides (≤1) ***LiSi*$_2$:** SiO_2 (57–80); Li_2O (11–19); K_2O (0–13); P_2O_5 (0–11); ZrO_2 (0–8); ZnO (0–8); other oxides and ceramic pigments (0–10)	Translucency	• Software program (UV WinLabTM 2.8; PerkinElmer) • Spectrophotometer (Lambda 35; PerkinElmer).

Table 1. *Cont.*

Study	Sample Cleaning Medium	Study Group and Sample Size	Material Composition	Optical Properties Assessed	Color Assessment Method
(Corcodel et al., 2021) [42] Germany	N/R	• ***White MZR:*** ✓ W-A2 ht white stained with Vita A2 (n = 12) ✓ W-A3.5 ht white stained with Vita A3.5 (n = 12) ✓ W-A4 ht white stained with Vita A4 (n = 12) • ***Pre-colored MZR:*** ✓ P-A2 ht precolored in A1 stained with Vita A2 (n = 12) ✓ P-A3.5 ht precolored in A3 stained with Vita A3.5 (n = 12) ✓ P-A4 ht precolored in A3 stained with Vita A4 (n = 12)	***MZR*:** Y_2O_3 (5%); HfO_2 (<3%); <2% Al_2O_3; SiO_2, and other oxides	Color stability	• Vita Classical color scale (Commission International d'Eclairage Lab standard, Peter Blattner; Switzerland). • Spectroradiometer (PR-670; SpectraScan, Photo Research, JADAK, a Novanta Company, North Syracuse, NY, USA) fitted with a MacroSpectar MS-75 lens (Photo Research) (JADAK, a Novanta Company, North Syracuse, NY, USA).
(Farzin et al., 2021) [43] Iran	99% isopropanol	• Super-high-translucent 5Y-TZP (DD cubeX^2) A2 ✓ External stain (Value stain [L-V]) (n = 8) ✓ External stain (Yellow stain [SPS-3]) (n = 8) • High-translucent 3Y-TZP-LA (DD Bio ZX^2) A2 ✓ External stain (Value stain [L-V]) (n = 8) ✓ External stain (Yellow stain [SPS-3]) (n = 8)	NR	Color stability Translucency Surface roughness	• CIELAB system • Spectrophotometer (VITA Easyshade; VITA Zahnfabrik)

Table 1. *Cont.*

Study	Sample Cleaning Medium	Study Group and Sample Size	Material Composition	Optical Properties Assessed	Color Assessment Method
(Sehovic et al., 2022) [44] Switzerland	Distilled water	• Porcelain-fused-to-metal (PFM) (control) (n = 15) • Pressable lithium disilicate ceramic (PC) (n = 30) • Machinable lithium disilicate ceramic (MC) (n = 45) • Zirconia (ZR) (n = 45)	***PFM*:** N/A ***PC*:** $Li_2Si_2O_5$ (70%); SiO_2 (57–80%); Li_2O (11–19%); K_2O (0–13%); P_2O_5 (0–11%); ZrO_2 (0–8%); ZnO (0–8%); other oxides and ceramic pigments (0–10%) ***MC*:** SiO_2 and other components: Li_2O, K_2O, MgO, Al_2O_3, P_2O_5 & other oxides ***ZR*:** ≥99% ZrO_2 + HfO_2 + Y_2O_3; Y_2O_3 > 4.5 ≤ 6.0%; HfO_2 ≤ 5.0%; Al_2O_3 + other oxides ≤ 1.0%	Color stability Gloss Surface roughness	• CIELAB system (illumination D65, observer 10°, CIELab, SCI). • Spectrophotometer (CM-508D; Konica Minolta) • Glossmeter (ZGM 1020 Glossmeter 45° Mini-measuring head; Zehntner GmbH, Sissach, Switzerland)
(Tavangar et al., 2021) [45] Iran	Distilled water	• ***MZR*:** ✓ Office value (OV) (n = 8) ✓ Office yellow (OY) (n = 8) ✓ Home value (HV) (n = 8) ✓ Home yellow (HY) (n = 8)	***MZR*:** Cubic zirconia system; 5Y-TZP; super high translucent ***Office bleaching agent*:** Opalescence Boost 40% H_2O_2 ***Home bleaching agent*:** Opalescence 20% $CH_6N_2O_3$	Color stability Translucency Surface roughness Surface hardness	• CIELAB system • Spectrophotometer (EasyShade V, VITA Zahnfabrik, Bad Säckingen, Germany)
(Raneem et al., 2021) [46] Saudi Arabia	Distilled water	• ***Control:*** ✓ Monochromatic ZR (n = 11) ✓ Colored ZR (n = 11) • ***Acid:*** ✓ Monochromatic ZR (n = 11) ✓ Colored ZR (n = 11) • ***Acid & brushing:*** ✓ Monochromatic ZR (n = 11) ✓ Colored ZR (n = 11)	NR	Color stability Gloss Surface hardness	• CIELAB system • Spectrophotometer (Labscan XE spectrophotometer, Hunterlab)

Table 1. *Cont.*

Study	Sample Cleaning Medium	Study Group and Sample Size	Material Composition	Optical Properties Assessed	Color Assessment Method
(Habib et al., 2021) [47] Egypt	Distilled water	• ***IPS Ivocolor:*** ✓ Mark II (n = 6) ✓ Empress CAD (n = 6) ✓ e.max CAD (n = 6) ✓ ZirCAD LT (n = 6) ✓ ZirCAD MT Multi (n = 6) ✓ Suprinity (n = 6) • ***VITA Akzent:*** ✓ Mark II (n = 6) ✓ Empress CAD (n = 6) ✓ e.max CAD (n = 6) ✓ ZirCAD LT (n = 6) ✓ ZirCAD MT Multi (n = 6) ✓ Suprinity (n = 6)	NR	Color stability Translucency Surface roughness	· CIELAB system· Spectrophotometer (Cary 5000 Spectrophotometer, Agilent Technologies, Santa Clara, CA, USA)
(Herpel et al., 2021) [48] Germany	70% alcohol solution	• ***White ZR disks:*** ✓ VITA A2 (n = 12) ✓ VITA A3.5 (n = 12) ✓ VITA A4 (n = 12)	***White ZR:*** ZrO_2; Y_2O_3 (5%); HfO_2 (<3%); Al_2O_3; SiO_2 (<1%).	Color stability	• CIELAB system • Spectroradiometer (SpectraScan PR-650, MS-75 lens, Photo Research Inc., Chatsworth, CA, USA)
(Lee et al., 2022) [49] Taiwan	NR	• 5 mol% yttria-partially stabilized zirconia (5Y-PSZ) (control) (n = 10) • VITA stain (VT) (n = 10) • SHOFU stain (SH) (n = 10) • Ivoclor stain (IV) (n = 10) • SHOFU glaze (GL) (n = 10)	ZR with 5 mol% yttria	Color stability Translucency Surface roughness	• CIELAB system • Spectrophotometer (Crystaleye, Model CE 100-DC/US, v1.3.1.0; Olympus, Tokyo, Japan)

Table 1. *Cont.*

Study	Sample Cleaning Medium	Study Group and Sample Size	Material Composition	Optical Properties Assessed	Color Assessment Method
(Lee et al., 2019) [50] Korea	Distilled water	• Polished surface and storage in distilled water (PDW) (n = 10) • Polished surface and brushed with a conventional dentifrice (PC) (n = 10) • Polished surface and brushed with a fluoride dentifrice (PF) (n = 10) • Polished surface and brushed with a whitening dentifrice (PW) (n = 10) • Glazed surface and storage in distilled water (GDW) (n = 10) • Glazed surface and brushed with a conventional dentifrice (GC) (n = 10) • Glazed surface and brushed with a fluoride dentifrice (GF) (n = 10) • Glazed surface and brushed with a whitening dentifrice (GW) (n = 10)	***MZR*:** ZrO_2; Y_2O_3 (4–6%); HfO_2 (5%); Al_2O_3 (1%); other oxides	Color stability Translucency Gloss Surface roughness	• CIELAB system • Spectrophotometer (EasyShade V, VITA Zahnfabrik, Bad Säckingen, Germany) • Glossmeter (WG60; FRU, Beijing, China)
(Mühlemann et al., 2021) [51] Switzerland	Distilled water	• ***Stained samples:*** ✓ Cerasmart (CER) (n = 15) ✓ VITA Enamic (ENA) (n = 15) ✓ Lava Ultimate (LVU) (n = 15) ✓ VITA Mark II (VM2) (n = 15) • ***Polished samples:*** ✓ Cerasmart (CER) (n = 15) ✓ VITA Enamic (ENA) (n = 15) ✓ Lava Ultimate (LVU) (n = 15) ✓ VITA Mark II (VM2) (n = 15)	***CER*:** 71 wt% nanoceramic fillers (silica 20 nm, barium glass 300 nm); Acrylate polymer network. ***ENA*:** 86 wt% (65 vol%) nanoceramic fillers (zirconia filler 4–11 nm, silica filler 20 nm, aggregated zirconia/silica cluster filler); 10 wt% (35 vol%) acrylate polymer matrix. ***LVU*:** 80 wt% (65 vol%) nanoceramic fillers (zirconia filler 4–11 nm, silica filler 20 nm, aggregated zirconia/silica cluster filler); 10 wt% (35 vol%) acrylate polymer matrix. ***VM2*:** <20 wt% feldspathic particles (average particle size 4 µm); >80 wt% glass matrix	Color stability Surface gloss	• CIELAB system • Spectrophotometer (CM-A145; SpectraMagic NX software, Konica Minolta, Tokyo, Japan) • Glossmeter (ZGM 1020 Glossmeter, 45-degree mini-measuring head, Zehntner)

Al_2O_3 = aluminum oxide; $CH_6N_2O_3$ = carbamide peroxide; Fe_2O_3 = ferric oxide; H_2O_2 = hydrogen peroxide; HfO_2 = hafnium oxide; K_2O = potassium oxide; Li_2O = lithium oxide; $Li_2Si_2O_5$ = lithium disilicate; MgO = magnesium oxide; MZR = monolithic zirconia; Na_2O = sodium oxide; NR = not reported; P_2O_5 = phosphorus pentoxide; SiO_2 = silicon dioxide; Y_2O_3 = yttrium oxide; ZnO = zinc oxide; ZR = zirconia; ZrO_2 = zirconium dioxide.

Regarding the different aging procedures, varying outcomes were reported. One study found that the impact of aging on the translucency of the tested materials was non-significant [40]. Moreover, a color change after aging was greater in the zirconia samples treated with polishing paste as compared to other surface treatments. However, in the lithium disilicate material, no significant variation in color change was observed among the groups with varying surface treatments [40]. Another study revealed that hydrothermal aging decreased the translucency over the aging time for all tested materials [41]. Additionally, the shade of industrially pre-shaded 4Y-TZP was not affected by high-speed sintering [41]. Habib et al. [47], revealed that chemical aging significantly influenced the optical properties (i.e., color stability and translucency) of stained monolithic ceramics.

Regarding grinding/occlusal adjustments, one study reported that the pre-colored monolithic zirconia is preferable when grinding is required since it is less susceptible to the color alteration from grinding and eventually reduces the risk for restoration failure because of unacceptable discoloration resulting from material removal [42]. Herpel and colleagues [48] revealed that the color of monolithic zirconia stained by color infiltration alters linearly with the depth of material removal. Furthermore, staining that is resistant to occlusal adjustments is possible if the staining solution infiltrates adequately deep into the ceramic structure [48]. Farzin et al. [43], reported that the first phase of staining with both stains (i.e., value stain and yellow stain) caused more color change in all types of monolithic zirconia. Additionally, translucency increased after glazing and decreased after the first and second staining [43].

In terms of toothbrushing, Sehovic et al. [44], found that the color and gloss of stained monolithic ceramic materials changed significantly using toothbrush abrasion in vitro. However, the color changes were below the threshold value for detection by the human eye (ΔE 1.8) [44]. Lee and co-workers [49] reported that toothbrushing had no effects on the color or translucency of the 5 mol% yttria-partially stabilized zirconia. Lee et al. [50], reported that brushing with several dentifrices markedly impacts the optical properties of monolithic zirconia finished with glazing or polishing procedures. Another study found that zirconia exposure to gastric acid with or without brushing will impact its color, irrespective of the application of coloring stains [46].

Regarding bleaching, bleaching with carbamide peroxide (i.e., home bleaching) 20% or hydrogen peroxide (i.e., office bleaching) 40% could perceptibly alter the color of externally stained monolithic zirconia, albeit within a clinically acceptable range [45]. Overall, all the included studies (100%) reported a significant decrease ($p < 0.05$) in the optical properties of monolithic zirconia samples as compared to those of other relevant ceramic materials, however, the change was clinically not perceivable in 25% ($n = 3/12$) of the included studies [44,45,48].

3.4. Quality Assessment Outcome

Eleven studies were graded as "moderate" quality [40–44,46–51], while only one study received an overall quality grade of "high" [45] (Table 3). All the included studies reported adequate *background and objectives (introduction)*, *intervention (methods)*, *outcomes (methods)*, *statistical analysis (methods)*, *and outcomes and estimation (results)* [40–51]. An adequate *abstract* was reported by all studies except one [50]. *Randomization* (*methods*) was conducted in five studies [44–46,50,51]; however, none of these studies reported the randomization procedure as well as the personnel involved in its implementation. A pre-determined *sample size calculation (methods)* was performed only by two studies [40,45]. All except two studies [41,51] reported the *limitations* in the discussion section. The *funding* status was mentioned by all but two studies [40,49], while three studies mentioned whether the *full trial protocol was accessible* [43,45,47] (Table 3).

Table 2. Outcomes related to optical properties of the materials assessed in the included studies.

	Outcomes				
Study	**Color Stability Outcomes (Mean ± SD)**	**Translucency (Mean ± SD)**	**Gloss (Mean ± SD)**	**Treatment (s)**	**General Outcomes**
(Kurt et al., 2019) [40]	***ZZ (p = 0.005 *)*:** G: 4.91 ± 1.23 R: 4.59 ± 1.42 P: 6.03 ± 0.78 ***IPS (p = 0.147)*:** G: 0.36 ± 0.19 R: 0.37 ± 0.31 P: 0.61 ± 0.36	***ZZ (p = 0.588)*:** G: −0.39 ± 0.57 R: −0.16 ± 0.36 P: −0.02 ± 0.65 ***IPS (p = 0.305)*:** G: −0.16 ± 0.26 R: −0.10 ± 0.62 P: −0.20 ± 0.34	N/A	Aging (accelerated artificial)	• Lithium disilicate ceramic was found to be more esthetic than monolithic zirconia ceramic in terms of color stability and translucency. • Color change after aging was higher in the zirconia specimens treated with polishing paste than other surface treatments. • However, in the lithium disilicate material, no significant difference in color change was found among the groups with different surface treatments.
(Lümkemann et al., 2021) [41]	N/A	***3Y-TZP*$_{0.25}$:** 7.2 ± 0.5 (p = 0.091) ***3Y-TZP*$_{0.05}$:** 6.5 ± 0.4 (p = 0.775) ***5Y-TZP*:** 19.4 ± 0.7 (p = 0.370) ***4Y-TZP*:** 13.6 ± 0.7 (p = 0.619) ***4Y-TZP*$_{speed}$:** 0.1 ± 0.0 (p < 0.001 *) $_{pre}$***4Y-TZP*$_{speed}$:** 9.0 ± 1.2 (p = 0.006 *) ***LiSi*$_2$:** 29.2 ± 1.7 (N/A)	N/A	Aging (hydrothermal)	• Hydrothermal aging decreased the translucency over the aging time for all tested materials. • The shade of industrially pre-shaded 4Y-TZP was not affected by high-speed sintering.
(Corcodel et al., 2021) [42]	***W-A2*:** 13.73 ± 0.45 (p > 0.05) ***W-A3.5*:** 13.53 ± 1.79 (p > 0.05) ***W-A4*:** 14.48 ± 0.28 (p > 0.05) ***P-A2*:** 2.39 ± 0.22 (p > 0.05) ***P-A3.5*:** 2.28 ± 0.28 (p > 0.05) ***P-A4*:** 2.64 ± 0.26 (p > 0.05)	N/A	N/A	Grinding	• Mechanical material removal had a significant effect on the color stability of both white and pre-colored MZR. • Pre-colored zirconia displayed less color change after grinding than white zirconia.
(Farzin et al., 2021) [43]	***Super-high cubeX*^{2}:** L-V: 3.88 ± 0.0 (p < 0.001 *) SPS-3: 9.32 ± 0.01 (p < 0.001 *) ***High ZX*^{2}:** L-V: 3.46 ± 0.03 (p < 0.001 *) SPS-3: 9.01 ± 0.02 (p < 0.001 *)	***Super-high cubeX*^{2}:** L-V: 16.20 ± 0.45 (p > 0.05) SPS-3: 14.33 ± 0.68 (p > 0.05) ***High ZX*^{2}:** L-V: 11.76 ± 0.33 (p > 0.05) SPS-3: 10.18 ± 1.02 (p > 0.05)	N/A	External staining	• The first stage of staining with both stains caused more color change in all types and thicknesses of monolithic zirconia. • Translucency increased after glazing and decreased after the first and second staining.

Table 2. *Cont.*

Outcomes					
(Sehovic et al., 2022) [44]	***PFM***: 0.29 ± 0.09 (p = 0.002 *) ***PC***: 0.73 ± 0.38 (p = 0.003 *) ***MC***: 0.69 ± 0.71 (p < 0.001 *) ***ZR***: 0.41 ± 0.22 (p = 0.003 *)	N/A	***PFM***: 48.32 ± 2.47 (p < 0.001 *) ***PC***: 48.32 ± 2.47 (p = 0.003 *) ***MC***: 51.51 ± 1.02 (p = 0.002 *) ***ZR***: 55.78 ± 0.43 (p = 0.002 *)	Toothbrushing	• Color and gloss of stained monolithic ceramic materials changed significantly by means of toothbrush abrasion in vitro. • Color changes were below the threshold value for the detection by the human eye (ΔE 1.8).
(Tavangar et al., 2021) [45]	***OV***: 2.06 ± 0.402 (p > 0.05) ***OY***: 2.71 ± 0.568 (p > 0.05) ***HV***: 2.28 ± 0.378 (p > 0.05) ***HY***: 2.81 ± 0.398 (p > 0.05)	***OV***: −0.724 ± 0.74 (p > 0.05) ***OY***: 0.782 ± 0.39 (p > 0.05) ***HV***: −1.019 ± 0.98 (p > 0.05) ***HY***: 0.112 ± 1.15 (p > 0.05)	N/A	Bleaching	• Bleaching of externally stained MZR with carbamide peroxide 20% (home bleaching) or H_2O_2 40% (office bleaching) could perceptibly change the color of externally stained monolithic zirconia, however it was within a clinically acceptable range.
(Raneem et al., 2021) [46]	***Control (p > 0.05)***: Monochromatic ZR: 0.12 ± 0.04 Colored ZR: 0.12 ± 0.06 ***Acid (p > 0.05)***: Monochromatic ZR: 2.91 ± 1.79 Colored ZR: 2.72 ± 1.09 ***Acid and brushing (p > 0.05)***: Monochromatic ZR: 3.38 ± 2.30 Colored ZR: 2.01 ± 1.33	N/A	***Control (p > 0.05)***: Monochromatic ZR: 175.83 ± 7.32 Colored ZR: 178.39 ± 5.93 ***Acid (p > 0.05)***: Monochromatic ZR: 185.21 ± 11.26 Colored ZR: 183.49 ± 5.2 ***Acid and brushing (p > 0.05)***: Monochromatic ZR: 181.23 ± 10.35 Colored ZR: 182.35 ± 4.33	Artificial gastric acid Toothbrushing	• Zirconia exposure to gastric acid with or without brushing will affect its color, regardless the application of coloring stains.
(Habib et al., 2021) [47]	***IPS Ivocolor (p < 0.001 *)***: Mark II: 5.11 Empress CAD: 5.24 e.max CAD: 4.55 ZirCAD LT: 3.87 ZirCAD MT Multi: 4.06 Suprinity: 4.80 ***VITA Akzent (p > 0.05)***: Mark II: 5.26 Empress CAD: 4.17 e.max CAD: 4.88 ZirCAD LT: 3.38 ZirCAD MT Multi: 3.62 Suprinity: 5.42	***IPS Ivocolor (p > 0.05)***: Mark II: 5.1 Empress CAD: 5.2 e.max CAD: 4.5 ZirCAD LT: 3.8 ZirCAD MT Multi: 4.0 Suprinity: 4.7 ***VITA Akzent (p > 0.05)***: Mark II: 5.5 Empress CAD: 4.1 e.max CAD: 4.8 ZirCAD LT: 3.3 ZirCAD MT Multi: 3.6 Suprinity: 5.4	N/A	Aging (chemical)	• Chemical aging had significantly changed the color and decreased the translucency of all stained monolithic ceramics.

Table 2. *Cont.*

Outcomes					
(Herpel et al., 2021) [48]	***V-A2*:** 13.7 ± 0.4 ($p < 0.05$ *) ***V-A3.5*:** 13.5 ± 1.7 ($p < 0.05$ *) ***V-A4*:** 14.5 ± 0.3 ($p < 0.05$ *)	N/A	N/A	Occlusal adjustment	• Up to 500 µm material removal, color difference changes linearly with the depth of material removal ($p < 0.05$). • Discolorations occur within clinically relevant occlusal adjustments of <100 um. • The effect is more severe with lighter, less saturated tooth colors.
(Lee et al., 2022) [49]	***5Y-PSZ (control)*:** 1.1 ($p > 0.05$) ***VT*:** 1.0 ($p > 0.05$) ***SH*:** 1.5 ($p > 0.05$) ***IV*:** 0.8 ($p > 0.05$) ***GL*:** 0.9 ($p > 0.05$)	***5Y-PSZ*:** 10.45 ± 0.76 ($p = 0.28$) ***VT*:** 5.94 ± 0.72 ($p = 0.28$) ***SH*:** 4.07 ± 0.35 ($p = 0.49$) ***IV*:** 5.67 ± 1.27 ($p = 0.03$ *) ***GL*:** 10.91 ± 0.66 ($p = 0.27$)	N/A	Toothbrushing	• Significant changes were found in the shade and translucency parameter values of 5Y-TZP after extrinsic staining ($p < 0.01$). • No significant changes were found after toothbrushing, irrespective of the staining brand ($p > 0.05$)
(Lee et al., 2019) [50]	***PDW*:** 0.3158 ± 0.1184 ($p > 0.05$) ***PC*:** 0.7164 ± 0.1670 ($p < 0.001$ *) ***PF*:** 0.7498 ± 0.2881 ($p > 0.05$) ***PW*:** 0.8106 ± 0.1946 ($p > 0.05$) ***GDW*:** 0.1953 ± 0.0690 ($p > 0.05$) ***GC*:** 0.301 ± 0.1687 ($p < 0.001$ *) ***GF*:** 0.3051 ± 0.1735 ($p < 0.001$ *) ***GW*:** 0.4846 ± 0.1600 ($p < 0.001$ *)	***PDW*:** 4.7731 ± 0.3186 ($p > 0.05$) ***PC*:** 4.7807 ± 0.2615 ($p > 0.05$) ***PF*:** 4.7464 ± 0.3464 ($p > 0.05$) ***PW*:** 4.7179 ± 0.4237 ($p > 0.05$) ***GDW*:** 4.7753 ± 0.2633 ($p > 0.05$) ***GC*:** 4.7831 ± 0.2908 ($p > 0.05$) ***GF*:** 4.6297 ± 0.2552 ($p > 0.05$) ***GW*:** 4.6115 ± 0.2533 ($p > 0.05$)	***PDW*:** 102.4 ± 19.98 ($p > 0.05$) ***PC*:** 101.33 ± 14.68 ($p > 0.05$) ***PF*:** 93.97 ± 19.32 ($p > 0.05$) ***PW*:** 86.6 ± 20.14 ($p > 0.05$) ***GDW*:** 85.2 ± 1.55 ($p > 0.05$) ***GC*:** 85.22 ± 1.13 ($p > 0.05$) ***GF*:** 83.2 ± 2.99 ($p > 0.05$) ***GW*:** 73.24 ± 5.98 ($p > 0.05$)	Toothbrushing	• Brushing with several dentifrices significantly compromised the optical properties of MZR finished with polishing or glazing methods.

Table 2. *Cont.*

		Outcomes			
(Mühlemann et al., 2021) [51]	***Stained samples***: CER: 3.35 ± 0.53 ($p < 0.001$ *) ENA: 0.31 ± 0.15 ($p < 0.004$ *) LVU: 1.27 ± 0.26 ($p < 0.004$ *) VM2: 0.62 ± 0.51 ($p < 0.001$ *) ***Polished samples***: CER: 0.88 ± 0.20 ($p < 0.004$ *) ENA: 0.23 ± 0.04 ($p < 0.004$ *) LVU: 0.35 ± 0.20 ($p < 0.004$ *) VM2: 0.32 ± 0.39 ($p < 0.001$ *)	N/A	***Stained samples***: CER: 32.7 ± 4.4 ($p < 0.001$ *) ENA: 35.0 ± 4.3 ($p < 0.001$ *) LVU: 21.4 ± 2.7 ($p < 0.001$ *) VM2: 28.6 ± 3.4 ($p < 0.001$ *) ***Polished samples***: CER: 52.8 ± 0.5 ($p < 0.001$ *) ENA: 47.0 ± 2.3 ($p = 0.024$ *) LVU: 50.3 ± 3.1 ($p < 0.001$ *) VM2: 51.6 ± 0.4 ($p < 0.001$ *)	Aging	• Color and gloss of stained resin-ceramic CAD/CAM materials changed significantly after aging by means of toothbrush abrasion in vitro.

* Represents a statistically significant difference. **Abbreviation:** 3Y-TZP = 3 mol% yttria-partially stabilized zirconia; 3Y-TZP$_{0.05}$ = Ceramill Zolid; 3Y-TZP$_{0.25}$ = Ceramill zi; 4Y-TZP = 4 mol% yttria-partially stabilized zirconia; 4Y-TZP = Ceramill Zolid ht+; 4Y-TZP$_{speed}$ = Ceramill Zolid ht+; 5Y-TZP = Ceramill Zolid fx; 5Y-TZP = 5 mol% yttria-partially stabilized zirconia; CER = cerasmart; ENA = VITA Enamic; GC = glazed surface and brushed with a conventional dentifrice; GDW = glazed surface and storage in distilled water; GF = glazed surface and brushed with a fluoride dentifrice; GL = SHOFU glaze; GW = glazed surface and brushed with a whitening dentifrice; HV = home value; HY = home yellow; IPS = Lithium disilicate glass-ceramic (e.max Press); IV = ivoclor stain; $LiSi_2$ = IPS e.max Press HT A4; L-V = value stain; LVU = Lava Ultimate; MC = machinable lithium disilicate ceramic; MZR = monolithic zirconia; N/A = not associated; OV = office value; OY = office yellow; P-A2 = ht pre-colored in A1 stained with Vita A2; P-A3.5 = ht pre-colored in A3 stained with Vita A3.5; P-A4 = ht pre-colored in A3 stained with Vita A4; PC = polished surface and brushed with a conventional dentifrice; PC = pressable lithium disilicate ceramic; PDW = polished surface and storage in distilled water; PF = polished surface and brushed with a fluoride dentifrice; PFM = porcelain-fused-to-metal; $_{pre}$4Y-TZP$_{speed}$ = Ceramill Zolid ht+ preshades A4; PW = polished surface and brushed with a whitening dentifrice; SH = SHOFU stain; SPS-3 = yellow stain; VM2 = VITA Mark II; VT = VITA stain; W-A2 = ht white stained with Vita A2; W-A3.5 = ht white stained with Vita A3.5; W-A4 = ht white stained with Vita A4; Y-TZP; = yttria-stabilized tetragonal zirconia polycrystal; ZR = zirconia; ZZ = monolithic zirconia (Zirkonzahn Prettau).

Table 3. Quality assessment of the included studies.

	Items															
Study	**Structured Abstract**	**Background (Introduction)**	**Objectives (Introduction)**	**Intervention (Methods)**	**Outcomes (Methods)**	**Sample Size (Methods)**	**Sequence Generation (Methods)**	**Allocation Concealment (Methods)**	**Implementation (Methods)**	**Blinding (Methods)**	**Statistical Anayis (Methods)**	**Outcomes (Results)**	**Limitations (Discussion)**	**Funding**	**Protocol**	**Score**	**Overall Quality**
(Kurt et al., 2019) [40]	✓	✓	✓	✓	✓	✓	X	X	X	X	✓	✓	✓	X	X	9	Moderate
(Lümkemann et al., 2021) [41]	✓	✓	✓	✓	✓	X	X	X	X	X	✓	✓	X	✓	X	8	Moderate
(Corcodel et al., 2021) [42]	✓	✓	✓	✓	✓	X	X	X	X	X	✓	✓	✓	✓	X	9	Moderate
(Farzin et al., 2021) [43]	✓	✓	✓	✓	✓	X	X	X	X	X	✓	✓	✓	✓	✓	10	Moderate
(Sehovic et al., 2022) [44]	✓	✓	✓	✓	✓	X	✓	X	X	X	✓	✓	✓	✓	X	10	Moderate
(Tavangar et al., 2021) [45]	✓	✓	✓	✓	✓	✓	✓	X	X	X	✓	✓	✓	✓	✓	12	High
(Raneem et al., 2021) [46]	✓	✓	✓	✓	✓	X	✓	X	X	X	✓	✓	✓	✓	X	10	Moderate
(Habib et al., 2021) [47]	✓	✓	✓	✓	✓	X	X	X	X	X	✓	✓	✓	✓	✓	10	Moderate
(Herpel et al., 2021) [48]	✓	✓	✓	✓	✓	X	X	X	X	X	✓	✓	✓	✓	X	9	Moderate
(Lee et al., 2022) [49]	✓	✓	✓	✓	✓	X	X	X	X	X	✓	✓	✓	X	X	8	Moderate
(Lee et al., 2019) [50]	X	✓	✓	✓	✓	X	✓	X	X	X	✓	✓	✓	✓	X	9	Moderate
(Mühlemann et al., 2021) [51]	✓	✓	✓	✓	✓	X	✓	X	X	X	✓	✓	✓	✓	X	9	Moderate

4. Discussion

This systematic review aimed to evaluate the influence of different treatments and conditions on the optical properties of monolithic zirconia as compared to other relevant ceramic materials. The optical properties (such as color stability, translucency, and surface gloss) of almost all the monolithic zirconia samples were significantly influenced by different treatments and conditions, including artificial, simulated, chemical, and hydrothermal aging, grinding/occlusal adjustment, glazing/external staining, toothbrushing, bleaching, and artificial gastric acid. For instance, according to Kurt et al. [40], a surface glaze could protect against aging impact for up to 1 year of clinical performance. Glazed monolithic zirconia demonstrated the greatest translucency parameters after and before artificial water spray aging as compared to those of only rubber polish with and without utilizing polishing paste [40].

The porosity generated on the surface after aging results in an increase in the incident light scattering that reduces translucency [52,53]. Moreover, after aging, the presence of the tetragonal and monoclinic stages in the structure decreases the translucency since the individual stage has varying refractive indices [52,54]. The aging method itself might be a variable influencing the optical properties of zirconia if varying methods are utilized. For example, constant immersion in a highly acidic solution simulating gastric acid with highly acidic pH (i.e., 1.2) at 37 °C for 4 days had a significant effect on the translucency of pre-sintered zirconia (i.e., 3-mol%Y-TZP; Prettau, Zirkonzhan, and Zenostar, Ivoclar Vivadent, Zirkonzahn, Atlanta, GA, USA) [46]. This protocol was repeated 208 times, representing four regurgitation sessions/week, for 12 months. This period under these specific conditions of time, temperature, and pH is regarded as equal to 10 years of clinical performance. Nevertheless, Kulkarni et al. [55] found that the utilization of acidic solution (i.e., pH = 2.0) with intermittent exposure (i.e., 2 min immersion, 2 min immersion in distilled water, and eventually 2 h storage in water at 37 °C) did not significantly influence the optical properties (i.e., translucency parameter) of zirconia ceramic. This procedure was repeated for a duration equal to 108 h of exposure [55].

Volpato and colleagues [56] found that the colorimetric features of zirconia were maintained after an accelerated aging procedure. Nonetheless, these investigators employed an aging method in an autoclave without exposure to ultraviolet light [47]. According to Dikicier and colleagues [57], the mean color difference in the zirconia samples was 1.29. This value is much lower than the mean color stability values reported by most of the studies included in this systematic review (i.e., <2.0). This outcome might be due to the utilization of the veneered samples fabricated from the colored pre-sintered block, and hence, a separate coloring method before sintering was not used by the authors of one of the included studies [40]. Some reports mentioned that color change in ceramics owing to aging might be related to metal oxides. Metallic pigments are incorporated for the color shading of ceramic, and these oxides are easily dissolved under ultraviolet light [57–59]. Consequently, in the present review, the significant color change in the zirconia might also be because of the dissolution of metallic oxides resulting from the ultraviolet radiation used during the aging protocol.

The association of aging with surface treatments also influences the color stability of ceramics. According to Atay and colleagues [60], the color change was greater in polished materials followed by the glazed materials after aging. In the present review, the color change score of the polishing paste-treated zirconia samples was revealed to be greater as compared to that of other relevant ceramic materials. Nevertheless, the color change score was not influenced by the surface treatment in the lithium disilicate material. Hence, it is indicated that the material in the polishing paste underwent interaction with the aging conditions and resulted in more differences in the color of zirconia samples.

The findings of this review revealed that lithium disilicate samples demonstrated significantly greater translucency as compared to monolithic zirconia samples, which is in agreement with the outcomes of several other studies [61–63]. Although the transparency of monolithic zirconia was increased as compared to traditional zirconia owing to the modifications performed while the production stage, it is still not comparable with even traditional lithium disilicate at the same material thickness.

The methodology-associated limitations of the included studies are important to recognize. First, most of the studies used zirconia from a single manufacturer. An amalgamation of varying shades and types of monolithic zirconia from multiple manufacturers is recommended since materials from different manufacturers may behave differently. Hence, it is recommended to use zirconia from multiple manufacturers in future experiments. Second, some studies performed aging for a limited time to simulate the clinical life of the prosthesis. Additionally, the aging process was performed only in water vapor and at standard temperatures. Further research should be performed over an extended period in the presence of different conditions, such as colored drinks, cigarettes, saliva, and different enzymes for a better reflection of clinical conditions. Third, 5 out of the 12 included studies did not assess the effect of translucency on the color of zirconia. It is recommended to incorporate translucency into the analysis and to investigate the color variations between different ceramic materials. Fourth, the in vitro studies permit standardization via the provision of a more precise estimate of the impact of material reduction alone on color stability in the absence of other potentially confounding variables, clinical studies are recommended for better reflection of the clinical setting of occlusal adjustments and restoration success based on the perception of patients. Moreover, most of the studies used zirconia with a similar yttria content. Zirconia with different yttria contents should be used in future investigations. Additionally, a few studies used one type of toothpaste with limited toothbrushing strokes. Since toothpaste with a higher amount of radioactive dentin abrasion will result in more intense wear of the characterized stains, it is recommended to perform a greater number of toothbrush strokes in future studies to assess the impacts of longer periods of simulated toothbrushing on the optical features of monolithic zirconia. Finally, enhancements in shade manufacturing and the optical characteristics of zirconia material are recommended to minimize the consequences of restoration failure and to ensure the long-lasting satisfaction of patients.

5. Conclusions

The optical features assessed for monolithic zirconia, such as color stability, translucency, and surface gloss, appeared to be compromised by various treatments and conditions, including aging, grinding/occlusal adjustment, glazing/external staining, toothbrushing, bleaching, and artificial gastric acid exposure. Due to the heterogeneity of the methodology and study conditions, it is recommended to perform future studies using standardized aging conditions (i.e., saliva, coloring drinks, cigarettes, and various enzymes), which reflect the clinical setting, using different stains of zirconia over an extended duration of aging to obtain conclusive evidence.

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