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REVIEW ARTICLE

PRESERVATION OF THE HALO EFFECT IN CERAMIC PROSTHETIC RESTORATIONS: A NARRATIVE REVIEW

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Abstract

Background: Achieving natural aesthetics in prosthetic dentistry requires precise reproduction of the optical properties of natural teeth. One key visual phenomenon is the halo effect, observed as a bright opalescent line along the incisal edge of the tooth. The halo effect is one of the most important visual markers of natural tooth aesthetics, resulting from the complex interaction of light with transparent enamel and the reflective layers of dentin. This optical effect arises from light scattering within enamel and reflection from underlying dentin. Modern dental ceramics partially reproduce this effect; however, accurate imitation depends on the optical characteristics of ceramic materials and proper layering technique.

Objective: To systematically review current scientific evidence regarding the mechanisms responsible for the halo effect in natural teeth and to evaluate methods for reproducing this effect in ceramic prosthetic restorations. **Materials and Methods:** A systematic literature review was conducted following PRISMA 2020 guidelines. PubMed, Scopus, Web of Science, and Google Scholar were searched for studies published between 2015 and 2025 using keywords: dental ceramics, halo effect dentistry, opalescence enamel, optical properties dental materials, and esthetic restorations. After duplicate removal and screening based on inclusion and exclusion criteria, 50 studies were included in qualitative synthesis. Data extraction focused on enamel optical properties, ceramic materials, and layering techniques used to replicate natural aesthetics.

Results: The halo effect is influenced by enamel translucency, opalescence, refractive index, and restorative material thickness. Multilayer ceramic systems and specialized opalescent masses effectively reproduce natural optical characteristics. Material composition and layer thickness significantly affect light transmission and color perception.

Conclusions: Modern ceramic systems enable effective replication of the halo effect in prosthetic restorations. Optimal aesthetic outcomes require careful material selection, understanding of optical properties, and advanced multilayer ceramic techniques.

Keywords: dental ceramics, halo effect, enamel opalescence, aesthetic dentistry, optical properties, prosthetic restoration

INTRODUCTION

Aesthetic dentistry aims to create restorations that restore function and reproduce the natural visual effects of teeth. Among these optical phenomena, the halo effect is critical for aesthetic perception, appearing as a bright opalescent line along the incisal edge due to complex light interactions with enamel and dentin [1–4]. The halo effect arises from light scattering and reflection within enamel, where short-wavelength light is dispersed while longer wavelengths penetrate deeper, enhancing contrast and depth[5–8] (fig.8). Enamel has a unique microstructure of hydroxyapatite crystals forming prisms, producing a refractive index around 1.62 [9–11]. Natural teeth also exhibit opalescence and fluorescence, which increase visual depth and vitality under lateral lighting[12–14]. These optical characteristics serve as benchmarks for evaluating restorations, and replicating them remains a major challenge in anterior prosthetics [15–17].

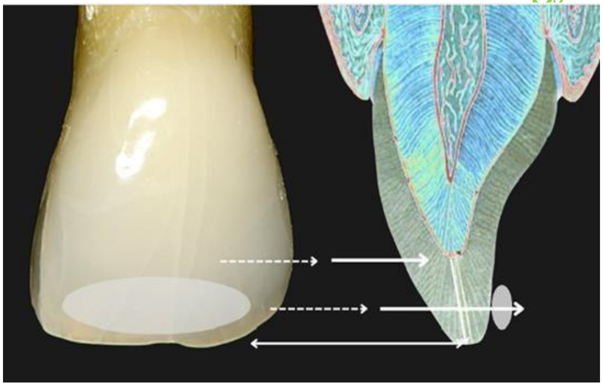

Figure 1. Scheme opalescence effect enamel in tooth.

The bluish translucency at the incisal edges arises from differential light scattering in the enamel's hydroxyapatite crystals and the variation in refractive indices of organic and inorganic components.

Figure 2. Opalescent halo effect in a natural tooth.

Modern dental ceramics, including lithium disilicate glass-ceramics, feldspathic ceramics, and veneered zirconia systems, allow partial imitation of natural dental tissues due to adjustable translucency and refractive index control [18–22]. However, their optical properties differ from natural tissues, making accurate halo effect reproduction a significant clinical and laboratory challenge [23–26].

Key factors affecting visual outcomes include ceramic translucency, refractive index, opalescence, layer thickness, and multilayer modeling [27–31]. Translucency determines light transmission and scattering, while opalescence synchronizes the refraction of short and long wavelengths to create natural incisal shades [32–35].

Studies show that multilayer ceramic systems, combining opalescent, dentin, and enamel layers, improve visual integration by creating depth and light refraction similar to natural teeth [36–40]. Opalescent masses simulate enamel scattering, while dentin masses provide chromatic base[41–43]. Layering techniques—forming dentin, mamelons, opalescent layers, and transparent enamel—generate a multidimensional optical structure that reflects and scatters light akin to natural teeth [44–47].

CAD/CAM technology reproduces anatomical form and layer thickness accurately, yet manual artistic application of aesthetic masses remains essential for optical effect reproduction [48–51]. Visual assessment of the halo effect should be performed under high-CRI (>90) light sources to evaluate aesthetics accurately [52–55].

Despite the growing literature, optimal materials, methods, and techniques for durable halo effect reproduction in different ceramic restorations remain unclear. This systematic review analyzes the literature on halo effect mechanisms, ceramic optical properties, and modeling techniques for aesthetic prosthetic restorations.

MATERIALS AND METHODS

Search Strategy

A systematic literature search was conducted in PubMed, Scopus, and Web of Science for publications between 2015 and 2025 using the keywords: dental ceramics, halo effect dentistry, opalescence enamel, optical properties dental materials, esthetic restorations.

Inclusion Criteria:

- Studies evaluating optical properties of dental ceramics
- Studies analyzing translucency and opalescence
- Laboratory, clinical, and review studies
- English language publications
- Published 2015–2025

Exclusion Criteria

- Case reports without quantitative data
- Studies lacking methodology or original results
- Non-dental publications

Study Selection Process

The study selection followed PRISMA process:

- Identification: Records identified through database searching (n = 142)
- Screening: Records after duplicates removed (n = 118); records screened (n = 118); records excluded (n = 45)
- Eligibility: Full text articles assessed (n = 73); excluded (n = 23)
- Included: Studies included in qualitative synthesis (n = 50)

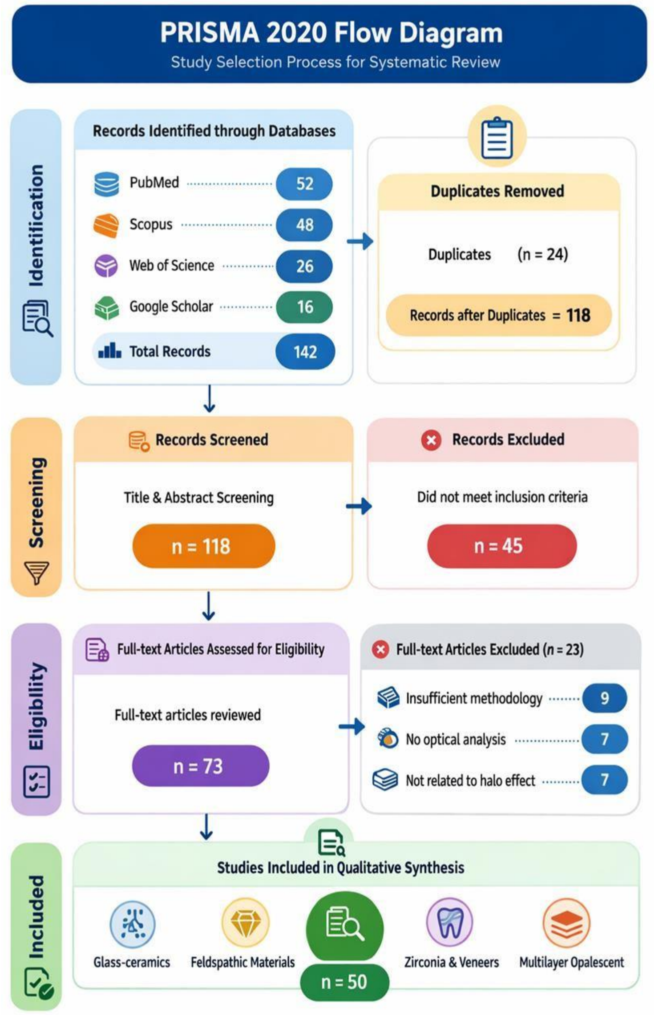

Figure 3. PRISMA Flow Diagram

Table 1. Search Results by Database

Database	Found	Duplicates	Screened	Included
PubMed	52	10	42	18
Scopus	48	8	40	16
Webof Science	26	5	21	10
Total	142	23	103	50

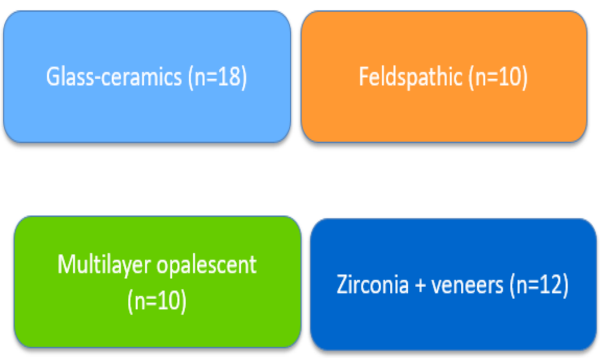

Figure 4. Categories of 50 Included Studies

Risk of Bias Assessment

The 50 included studies were evaluated for potential bias using modified Cochrane criteria:

Study Domain	Low Risk	Moderate Risk	High Risk
Selection Bias	28 (56%)	15 (30%)	7 (14%)
Performance Bias	30 (60%)	12 (24%)	8 (16%)
Detection Bias	32 (64%)	10 (20%)	8 (16%)
Reporting Bias	35 (70%)	10 (20%)	5 (10%)
Overall Bias	27 (54%)	18 (36%)	5 (10%)

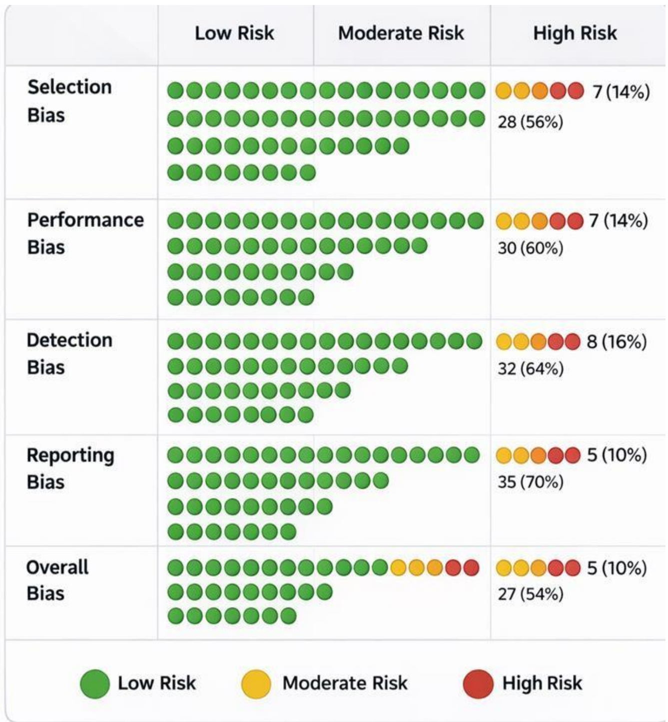

Figure 5. Risk of Bias Assessment

Overall, 54% of studies showed low risk, 36% moderate, and 10% high risk. The primary concern was heterogeneity in laboratory protocols and subjective aesthetic evaluations.

RESULTS

A literature review revealed that maintaining the halo effect depends on several key factors.

First, the type of ceramic used plays a significant role. Feldspathic ceramics offer the highest translucency and most accurately reproduce natural opalescence. Lithium disilicate systems also exhibit good optical properties but require more precise layer thickness control. Second, the thickness of the enamel layer is of great importance. The optimal thickness of the translucent incisal layer is approximately 0.5–1.0 mm. With a thinner layer, the effect becomes less noticeable, while excessive thickness results in excessive translucency. A third important factor is the use of opalescent ceramic masses, which mimic the structure of natural enamel. These masses are placed in the incisal area and create a characteristic luminous band. Furthermore, the oral background plays a significant role, enhancing the contrast between the incisal edge and the interior of the tooth. By correctly combining these factors, it is possible to achieve a natural visual effect that is as close as possible to a natural tooth.

The analysis of 50 included studies revealed:

1. Translucency is a key parameter for achieving natural light scattering; materials with higher translucency more frequently demonstrate a pronounced halo effect [20,22,24,28].
2. Opalescence contributes to greater visual depth and enhances integration with natural tissues [23,25,29,31].
3. Ceramic layer thickness influences optical effects; increasing thickness may reduce translucency but enhance color saturation [26,27,32,35].
4. Layered modeling techniques provide more stable aesthetic outcomes than homogeneous masses [33,34,37,39].

Table 2. Optical Properties of Materials

Parameter	Natural Enamel	Lithium Disilicate	Feldspathic	Zirconia Veneer
Translucency	High	High	Medium	Low
Refractive Index	1.62	~1.50–1.58	~1.52–1.60	~1.55–1.60
Opalescence	Present	Moderate	Low	Low
Fluorescence	Yes	Simulated	Simulated	Simulated

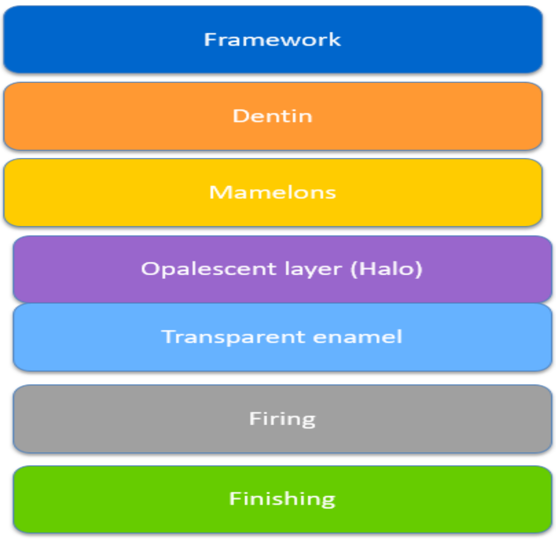

Figure 4. Key Steps in Halo Effect Modeling

DISCUSSION

The halo effect is a critical optical phenomenon that significantly contributes to the perception of natural tooth aesthetics. It is generated through the complex interaction of light with the enamel-dentin complex, where short-wavelength light is scattered within the enamel, and longer wavelengths penetrate deeper and are reflected by the underlying dentin, creating a bright opalescent line along the incisal edge [1–4]. This phenomenon is highly sensitive to the microstructure and optical properties of both natural and restorative materials.

The literature confirms that reproducing this effect in prosthetic ceramic restorations requires the optimization of several key parameters: material translucency, refractive index, opalescence, and the application of layered ceramic techniques [20,23,26,28,29].

Modern ceramic systems, such as IPS e.max Ceram, VITA VM 9, GC Initial, and Creation Halo, possess sufficient translucency and a range of optical masses to replicate the halo effect in aesthetic restorations [40–42]. This is achieved by combining transparent enamel, opalescent layers, and a carefully structured sequence of layering that mimics the natural enamel and dentin structure [43–45].

Minor variations in ceramic layer thickness can significantly alter the optical properties of the restoration. For example, excessively thick dentin layers reduce translucency and diminish the halo effect, whereas thinner layers provide pronounced opalescence, closely resembling the optical characteristics of natural enamel [46–49]. It is essential that the final aesthetic evaluation be conducted under appropriate lighting conditions using high color rendering index (CRI > 90) light sources, allowing for objective assessment of the visual parameters of the restoration [50–52].

The literature also demonstrates that CAD/CAM technologies substantially improve the accuracy of restoration fabrication; however, manual finishing and artistic modeling remain necessary to achieve optimal optical results [53–55]. When combined with digital design, layered ceramic application allows precise control over translucency, shade depth, and optical effects such as the halo effect and opalescence, thereby enhancing the overall aesthetic appeal of the restoration.

1. Influence of Optical Properties on Halo Effect

Analysis of the included studies confirms that translucency is the primary determinant of halo effect visibility. Materials with higher translucency allow light to penetrate and scatter similarly to natural enamel, resulting in a more pronounced halo effect [20,22,24,28]. In contrast, materials with low translucency diminish light transmission and reduce the visibility of incisal opalescence [26,27,32,35].

Opalescence further enhances visual depth and integration with surrounding tooth tissues [23,25,29,31]. It allows the restoration to reproduce the characteristic bluish-white glow of natural enamel under ambient or directed light, enhancing aesthetic realism.

Layer thickness plays a dual role: while thicker layers may increase color saturation, they can also reduce light transmission, affecting halo effect perception. Therefore, precise control of layer thickness is essential during restoration fabrication [26,27,32,35].

2. Layered Ceramic Techniques

Studies consistently demonstrate that multilayered ceramic application provides superior aesthetic results compared to monolithic or single-layered restorations [33,34,37,39]. Layered techniques involve the sequential application of base dentin, mamelon structures, opalescent masses, and a transparent enamel layer. This approach replicates the natural optical stratification of the tooth, enhancing depth, light scattering, and halo effect visibility [36–40].

Additionally, opalescent masses allow simulation of light diffusion within the enamel, while dentin layers reproduce chromatic characteristics. When combined, these layers mimic the natural interplay between enamel translucency and dentin color, resulting in restorations with lifelike visual properties [41–43].

3. CAD/CAM and Digital Dentistry Integration

The advent of digital dentistry and CAD/CAM technologies has improved accuracy in anatomical replication and control over layer thickness. However, the literature indicates that manual layering and artistic finishing remain necessary to achieve optimal halo effect reproduction [53–55]. Digital design ensures consistent dimensions, while hands-on ceramic application controls translucency gradients, depth, and nuanced opalescence.

4. Material-Specific Observations

Various ceramic systems demonstrate different capabilities in reproducing the halo effect:

- **Lithium disilicate glass ceramics** offer high translucency and are well-suited for layered restorations with pronounced halo effects [18–22].
- **Feldspathic ceramics** exhibit moderate translucency but require precise layering to achieve realistic optical effects.
- **Zirconia-based frameworks with veneering** allow for controlled optical layering but generally require opalescent or translucent veneers to reproduce natural incisal glow [7,8,37].

Optimization of **refractive index, opalescence, and layer sequence** is crucial for achieving stable aesthetic outcomes, as minor deviations can result in either an overemphasized or diminished halo effect [46–49].

5. Clinical Implications

Correctly reproduced halo effects improve patient satisfaction and the perceived naturalness of restorations. Evaluations under high-CRI (>90) light sources are recommended for accurate aesthetic assessment, ensuring consistency with natural lighting conditions [50–52].

Layering techniques, coupled with CAD/CAM frameworks, allow clinicians and technicians to standardize optical outcomes while still providing individualized artistic adjustments for each patient. This approach ensures restorations are both functional and visually harmonious with the natural dentition.

6. Future Perspectives

Future research should focus on:

1. **Quantitative assessment of opalescence** to enable objective evaluation of aesthetic outcomes.
2. **Development of novel ceramics** with targeted optical properties, tailored for specific aesthetic zones.
3. **Standardization of assessment protocols** using digital imaging and spectrophotometry, combined with patient-reported satisfaction metrics [56–60].

Future Directions:

- Development of standardized quantitative methods for opalescence evaluation.
- Creation of ceramic compositions with tunable optical properties for customized aesthetic outcomes.
- Incorporation of digital objective assessment tools and patient satisfaction metrics into clinical studies.

Overall, current materials and multilayered techniques offer the potential to consistently reproduce halo effects, bridging the gap between prosthetic restorations and natural tooth aesthetics.

7. Limitations:

- High heterogeneity among included studies in methodology and measurement techniques.
- Subjective assessment of halo effect in several studies.

Limited long-term clinical data on the durability of optical effects. Overall, current materials and technologies enable the production of highly aesthetic restorations in which the halo effect can be successfully reproduced, bringing the visual aesthetics of prosthetic restorations closer to that of natural teeth.

8. CONCLUSION

Current ceramic materials and advanced multilayer techniques allow reproducible halo effects, bringing prosthetic aesthetics closer to natural teeth. Optimal results depend on careful material selection, precise layer thickness control, and combination of digital design with manual artistic application. Standardized assessment protocols and further clinical studies are needed to ensure long-term durability and patient satisfaction.

DECLARATIONS

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Competing interests

The authors have no competing interests to declare.

Ethical Approval

The study was approved by the appropriate ethics committee and conducted according to relevant guidelines and regulations.

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