REVIEW ARTICLE

Use of Restorative Full Crowns Made with Zirconia in Children: A Systematic Review

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Abstract

Aim and objective: The purpose of this systematic review is to analyze the suitability of the zirconia crowns for restoration of damaged primary teeth in children.

Background: This systematic review has been conducted in line with the preferred reporting items for systematic reviews (which is also called as PRISMA) guidelines. A search for the relevant articles of zirconia crowns in deciduous teeth has been made in electronic database of PubMed and a study design (meta-analysis), i.e., PICOS framework. The words used in the search are "zirconia crowns" and "primary molars," "zirconia crowns" and "primary incisors," "zirconia crowns" and "children," "zirconia crowns" and "primary teeth."

Review results: The database search showed 44 studies of which 20 articles were excluded as they were irrelevant, duplicates, and data were not available. In the present systematic review, the remaining 24 articles were included.

Conclusion: Zirconia crowns have been proved with better results than other crowns in terms of gingival and periodontal health, esthetics, and crown fractures. However, the quantity of tooth preparation and the wear of antagonist tooth are reported to be more in case of zirconia crowns. Future randomized control studies should be carried out in primary teeth due to less number of randomized studies on this topic.

Clinical significance: Zirconia crowns are now widely used in dentistry and there is an increase in the number of studies, so a systematic review evaluating and comparing results is warranted.

Keywords: Esthetics, Pediatric zirconia crowns, Primary dentition, Primary teeth, Restorations, Systematic review.

International Journal of Clinical Pediatric Dentistry (2020): 10.5005/jp-journals-10005-1822

Background

More esthetic demand of the parents and patients for restoration of the decayed and damaged primary teeth has led to the availability of different esthetic preformed crowns.[1] For pediatric dentists, the esthetic rehabilitation of severely damaged deciduous teeth is one of the greatest challenges. Various techniques have been attempted over the years in restoring the teeth. Some of them are polycarbonate crowns, acid-etched crown, stainless steel crown (SSC), strip crowns, open-faced SSC with veneer placed on chair side, and commercially available pre-veneered SSC.[1] The viable and productive use of these strategies is convoluted because of technical, utilitarian, or esthetic hurdles.[2]

Prefabricated zirconia crown is a solid ceramic crown that offers better esthetics and is a biocompatible full-coverage restoration for deciduous teeth.[2,3] EZ-Pedo (EZ-Pedo, Loomis, CA, USA) was the first pediatric zirconia crown commercially accessible in the United States, found by Dr John Hansen and Dr Jeffrey Fisher and initially advertised in 2008.[1] Use of all ceramic restorations has expanded as various different brands (NuSmile ZR Primary Crowns, Houston, TX, USA; Kinder Krowns, St. Louis Park, MN, USA; Hu-Friedy Mfg. Co., LLC, Chicago, IL, USA; and Cheng Crowns, Exton, PA, USA) were additionally made as pediatric zirconia products.[3,4] They are anatomically shaped, metal-free, totally bioinactive, and impervious to decay.[1,3]

Since zirconia restorations are of extraordinary intrigue and there is an expansion in the number of studies, a systematic review assessing and contrasting outcomes is necessitate. The point of this study was to efficiently look and audit accessible investigations detailing the outcomes from clinical preliminaries and *in vitro* studies. The objective was to make an arsenal of the current writing to plot the data on preparation, clinical execution, and to analyze and discuss about the intricacies to give clinicians accommodating thoughts in the dynamic cycle of when and where the utilization of zirconia crowns is relevant in children.

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How to cite this article: Ajayakumar LP, Chowdhary N, Reddy VR, *et al*. Use of Restorative Full Crowns Made with Zirconia in Children: A Systematic Review. Int J Clin Pediatr Dent 2020;13(5):551–558.

Source of support: Nil

Conflict of interest: None

Materials and Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines.[5] Before the start of the review, following the recommendations of the *Cochrane Handbook for Systematic Reviews of Interventions*, a review methodology was established.[6]

Focused Question

The focused question was the success of zirconia crowns in pediatric patients?

Outcome Measures

The outcome variables measured in this review were the following:

- Patient satisfaction
- Long-term success of zirconia crowns when used in children

Search Strategy

A comprehensive bibliographic search was conducted in MEDLINE/PubMed to collect relevant articles published till January 2020 with no limitation on the language and year of publication. The PRISMA statement guidelines with predetermined search strategy were used (Table 1). Furthermore, hand search was performed in the reference sections of the studies included (cross-referencing). The following search terms were used for literature search. "zirconia crowns" AND "primary molars" ("zirconia crowns"[All Fields] AND "primary molars"[All Fields]), "zirconia crowns" AND "primary incisors" ("zirconia crowns"[All Fields] AND "primary incisors"[All Fields]), "zirconia crowns" AND "children" ("zirconia crowns"[All Fields] AND "children"[All Fields]), "zirconia crowns" AND "primary teeth" ("zirconia crowns"[All Fields] AND "primary teeth"[All Fields]).

Selection Criteria

This review included *in vitro* studies and case reports that used zirconia crowns in children.

Inclusion Criteria

The inclusion criteria for selection of studies were (1) clinical trial (prospective or retrospective), randomized control studies reporting on zirconia crowns in deciduous teeth; (2) *in vitro* studies involving pediatric zirconia crowns; (3) articles that studied the acceptance and preference of esthetic crowns by dentists, parents, and children were also included in the review.

Exclusion Criteria

The exclusion criteria included the articles that investigated the effectiveness of zirconia crowns on permanent teeth.

Screening and Selection

Two authors (LP, NC) performed the search and screening process (κ value = 0.83, which indicated near-perfect agreement between the two authors). At first titles and abstracts were analyzed followed by the full-text articles, which were then selected and analyzed with careful and thorough reading based on the inclusion and exclusion criteria for the future data extraction. Any disagreements between the authors with the selection or rejection of studies were resolved carefully with thorough discussion.

Table 1: Systematic search strategy (PICOS strategy)

Search strategy	
Population	Primary teeth
Intervention	Zirconia crowns
Comparison	Success rates and outcomes of zirconia crowns
Outcome	Gingival health, tooth preparation, survival rate
Study design	Randomized control trials, controlled clinical trials, prospective studies

Data Extraction

The data extraction procedure was carried out by the first author and then redefined by the second author. Data extraction was done independently from each full-text articles that met the inclusion criteria; it is done in a standardized form in the electronic format (Office Excel 2013 software, Microsoft Corporation). Information was classified under author/year, type of study, duration of the study, sample size and conclusion.

Assessment of Risk of Bias and Quality

In order to have quality appraisal, the below factors were analyzed by the CRIS guidelines[7] for *in vitro* studies: (1) sample planning/handling; (2) sequence distribution and randomization measures; (3) the evaluators were blinded or not; and (4) statistical analysis. Studies with data about whole factors were regarded to be of acceptable quality; those with presence of two to three factors were considered as reasonable quality; lastly remaining were delegated of low quality when none or only one perspective was secured.

Review Results

Search and Selection

Selection criteria were based on the PRISMA statement flow chart (Flowchart 1). The database search (P) resulted in 44 studies of which 20 articles were excluded as they were irrelevant, duplicates, and data were not available. The remaining 24 full-text articles were evaluated for their eligibility and were included in the present systematic review (Flowchart 1).

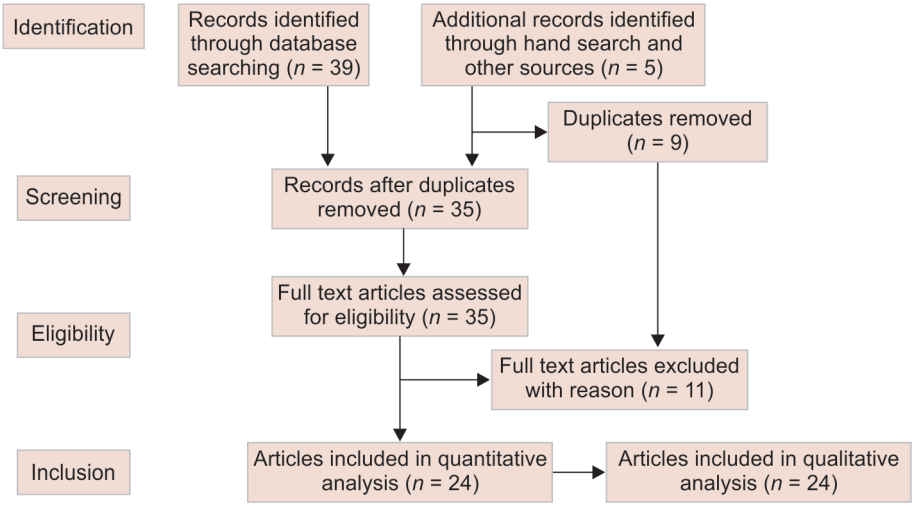
Discussion

Zirconia is a crystalline dioxide of zirconium and is a polymorph that is available in three different forms that are monoclinic (M), tetragonal (T), and cubic (C).[2] The mechanical properties of zirconia are similar to that of metal, and has color similar to that of teeth.[2] At room temperature, pure zirconia is in the monoclinic phase and remains stable up to 1170°C. At 2370°C, it transforms to a tetragonal and then into a cubic phase. On cooling, i.e., in a temperature range from 100°C to 1070°C, the tetragonal phase transforms back to monoclinic.[4] A volume expansion of approximately 3–4% occurs on cooling along with the phase transformation.[4] Crack and its propagation is prevented in zirconia due to their transformation from one crystalline phase to another, and the resultant volume increase.[1]

Zirconia is known to have excellent biocompatibility and high wear and corrosion resistance.[8,9] Zirconia is of three types: yttria-stabilized tetragonal zirconia polycrystal (Y-TZP), magnesia partially stabilized zirconia, and zirconia-toughened alumina. Yttria-stabilized tetragonal zirconia polycrystal is a monolithic zirconia, which consists of partially stabilized tetragonal grains that are equiaxed.[8] Because of their superior mechanical properties, these materials have wide range of clinical applications from implant abutments and single-tooth restorations to fixed partial dentures.[10,11] Recently, the prefabricated zirconium dioxide ceramic crowns are being used in the treatment of deciduous teeth to provide a more durable and esthetic alternative.[12]

In case of crown placement, tooth preparation and cementation procedures are the two important steps. Adequate clearance, proper angulations, and knife edge finish lines are necessary to preserve gingival health and promote less plaque accumulation.[1] Adequate preparation of the tooth will fundamentally improve

Flowchart 1: PRISMA flow diagram of screening and selection process



esthetics; crown fit reduces chances of crack of the veneer and saves chairside time. The tooth must be prepared to fit the crown, so the crown fits the tooth inactively without utilizing pressure.[13,14]

The preparation of tooth takes more time for zirconia crowns and it is difficult to adjust a zirconia crown since it is ceramic and cannot be trimmed with scissors like the SSC. Hence, it is mandatory to use a high-speed, fine diamond bur with plenty of water since excessive heat can create fractures in the ceramic structure of the crown.[1] Occlusal and proximal adjustments are not recommended, because it might affect the crown's glaze and create a weak area of thin ceramic. Zirconia crowns should fit passively and do not try to seat the crown with force, because it will result in the fracture of the crown as they are made up of solid zirconia. The appropriate size of the crown should be in such a way that it fit passively and subgingivally without distorting the gingival tissue.[13,14]

The manufacturers of the NuSmile ZR crown have provided tooth preparation guidelines on their website, where they recommend a reduction of 1–2 mm on the occlusal surface, maintaining the natural contour; a 0.5–1.25 mm circumferential reduction; and a feather edge of approximately 1–2 mm subgingivally.[15] In the study by Lee et al., they demonstrated a reduction of 0.6–0.8 mm in the occlusal surface and in the circumferential axial wall, and a reduction of 0.2–0.4 mm in the cervical aspect of the tooth for receiving pediatric zirconia crowns. This difference may be related to space for the cement.[16] The smaller cement space affords mechanical advantages.[17] But such minimal tooth reduction is not feasible in the clinical scenario, when the thickness of crown is considered. The cement space required for the zirconia crown is still unclear, but can be about 0.2 mm—as observed from previous studies due to 0.2 mm internal occlusal gap.[17–19]

However, an additional space of 0.2–0.3 mm might be required for clinical convenience, and indeed, this may vary with the clinical scenarios. Considering these factors, Lee et al. suggested a reduction of 1.3 mm of the cusp and a reduction of 1.1 mm on the fossa than the recommendations given by the manufacturers. The mesiodistal distance is important when selecting a crown. Thus, preparations in the interproximal area should extend for about 1 mm, as the thickness of the zirconia crown is up to 0.8 mm at the contact area. The amount of buccal and lingual reductions should be according to the status of the abutment teeth.[16]

In a clinical report, Lee presented a guideline regarding the clinical and laboratory techniques for managing traumatized maxillary incisors utilizing zirconia crown where a polyvinyl siloxane enlistment material was utilized as the impression material and two indistinguishable casts were made. He made three reduction guides after tooth preparation on the casts and used ultrasonic burs for the subgingival preparation, which prevented gingival injuries. With the help of these reduction guides, he prepared the discolored incisor, which in turn helped in wiping out the mystery engaged with tooth planning making it exact and quick; no hemorrhage control was necessary, since the subgingival preparation was finished utilizing ultrasonic burs. After 8 days, he saw that the zirconia crown gave an ideal esthetic outcome and gingival health.[20]

An alternative technique for restoring mutilated primary incisors using zirconia crowns was advocated by Shahawy et al., where after pulpectomy, 3 mm of the coronal part of the root filling was taken out to give space for the core material. The core material was then consolidated into the readied intracanal space broadening 3 mm supragingivally and the material was permitted to set and utilizing a high-speed diamond bur the supragingival core was then prepared and the crown preparation was stretched out to give a finish line within the sound tooth structure subgingival to the core material. The Nusmile ZR crowns were then cemented utilizing Fuji IX. The patient showed astounding gingival reaction following 2 years and one of the crowns (the maxillary left central incisor) had unstuck because of injury. The patients were reviewed for a span of two years with an interval of six months and reasoned that this method would offer a helpful restorative choice to guardians of little youngsters with seriously damaged teeth.[21] The outcomes by Walia et al.[22] and Abdulhadi et al.[23] favored zirconia crowns regarding retention and the gingival health (Table 2). This could be because of the biocompatibility of zircon and furthermore the cleaned and smooth surface, prompting less plaque gathering and consequently less gingival irritation.[22]

The major concern in utilizing these crowns was the propensity towards expanded wear on the antagonist teeth as seen by Walia et al.[22] In contrast to this, Choi et al.[24] had expressed that there was no much contrast in the measure of wear of deciduous teeth brought about by that of stainless steel crowns and the zirconia crowns, but this was an *in vitro* study, hence further clinical trials are required to come into a resolution with respect to the wear of the antagonist teeth caused by zirconia crowns.

Regarding the fracture load and effect of chewing stimulation, zirconia crowns showed 100% survival rate than the SSCs in an

Table 2: Main characteristics of the studies

Author (year)	*Type of study*	*Follow-up*	*Crowns used*	*No. of crowns*	*Anterior/posterior*	*Conclusion*
Walia et al. (2014)[22]	RCT	6 months	Strip crowns, pre-veneered SSCs, zirconia crowns	129	Anteriors	Zirconia crown were found to be gingival friendly and retentive.
Shahawy et al. (2016)[21]	Clinical study	24 months	Zirconia crowns	86	Anteriors	Glass ionomer retained zirconia crowns for severely mutilated primary anterior teeth.
Abdulhadi et al. (2017)[23]	RCT	12 months	Zirconia crowns, SSCs	120	Posteriors	Zirconia crowns offered better gingival health than SSCs.
Kist et al. (2019)[25]	*In vitro* study	–	Sprig EzCrowns, Kinder Krowns, NuSmile Zirconia, computer- aided design/computer-aided manufacturing (CAD/CAM)-designed zirconia crown, NuSmile Signature, SSC	36	Posteriors	All the zirconia and pre-veneered SSCs showed a 100% survival rate while the SSCs showed a survival rate of only 41.7%.
Diener et al. (2019)[12]	*In vitro* study	–	Cheng Crowns Zirconia EZCrowns NuSmile ZR Zirconia Pediatric Crowns	40	–	Significant differences in surface roughness parameters were observed among the crowns, thus differences in their clinical performance can be anticipated.
Pani et al.(2016)[33]	Questionnaire	–	Open-faced SSCs, strip crown, zirconia crown	–	Anteriors	Zirconia crown was most accepted.
Khatri (2017)[1]	Case report	–	Zirconia crown	1	Anterior	Offered high-end esthetics, superior durability, and easy placement compared to composite restorations and strip crowns.
Mathew et al., (2020)[26]	RCT	12 months	Zirconia crown, SSCs	60	Posteriors	When compared to SSCs, zirconia crowns prevents adhesion of *S. mutans* onto its surface. Thus reducing plaque accumulation around the crown and inflammation of surrounding gingiva.
Choi et al. (2015)[24]	*In vitro* study	–	Zirconia crowns, SSCs, leucite glass ceramic, lithium disilicate glass ceramic	40	Anteriors	Not much significant difference was seen on the antagonist tooth wear between SSCs and zirconia crowns.
Pozo et al., (2014)[29]	Case report	2 months	Zirconia crown	4	Anteriors	Zirconia crowns represent a new approach and an esthetic alternative to restore the natural appearance of a child's teeth that is compromised by caries or trauma.
Holsinger et al., (2016)[34]	Retrospective cross-sectional study	8 months	Zirconia crown	57	Anteriors	Zirconia crowns are clinically acceptable restorations in the primary maxillary anterior dentition. Parental satisfaction with zirconia crowns was high.
Halawany et al. (2017)[30]	Cross-sectional survey	–	–	–	Both	Pre-veneered or zirconia crowns are underutilized by pediatric dentists whereas the use of SSCs was high.
Cazaux et al. (2017)[35]	Case report	29 months	EZ-Pedo crowns	1	Posterior	A good integration of the crown with no unusual attrition of the opposing tooth.

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Author (year)	Type of study	Follow-up	Crowns used	No. of crowns	Anterior/posterior	Conclusion
Lee et al. (2019)[16]	*In vitro* study	–	NuSmile ZR, SSCs	10	Posteriors	The amount of tooth reduction required was more for posterior zirconia crowns than for SSCs. The occlusal surface requires more tooth reduction than the axial surface and the gingival margins for zirconia crowns.
Lee (2018)[20]	Case report	8 days	NuSmile ZR crowns	1	Anterior	Advocated the use of reduction guides for an accurate and fast tooth preparation.
Taran and Kaya (2018)[28]	Prospective controlled clinical trial	12 months	Zirconia crowns, SSCs	30	Posteriors	Gingival health and plaque accumulation performance of zirconia crowns were better than those of SSCs.
Ashima et al. (2014)[36]	Case report	30 months	Zirconia crowns	4	Anteriors	Zirconia crowns can be a simple, effective, and a promising alternative for rehabilitation of severely decayed or fractured primary anterior teeth due to their advantages, which include working time, esthetics, and improvement in microstructure.
Walia et al. (2018)[37]	*In vitro* study	–	Cheng, Sprig EZCrowns, NuSmile, Kinder Krowns	40	Posteriors	All of the four posterior primary zirconia crowns had different surface profiles. Cheng crowns had the smoothest occlusal surface and occlusal edges for both primary first and second molars.
Azab et al. (2019)[38]	RCT	36 months	Zirconia crowns luted with bio-active cement and packable glass ionomer	50	Posteriors	Packable glass ionomer is more retentive than bio-active cement when used for cementing zirconia crowns. Posterior pediatric zirconia crowns have high fracture resistance after 36 months of clinical performance, irrespective of the luting cement used. Luting cement for zirconia pediatric crowns has no effects on the condition of gingiva around crowns.
Townsend et al. (2014)[3]	*In vitro* study	–	EZ-Pedo, NuSmile, Kinder Krowns, pre-veneered SSCs	20	Posteriors	The force required to fracture the EZ-Pedo crown was higher than that required for NuSmile and Kinder Krowns. The forces required to fracture the pre-veneered SSCs were greater than the forces required to fracture the other types of zirconia crowns.
Seminario et al. (2019)[39]	Clinical study	36 months	Zirconia crowns	94	Anteriors	Zirconia crowns can be a used as an esthetic alternative for reconstruction of primary maxillary anteriors in children.
Al-Haj Ali (2019)[40]	*In vitro* study	–	SSCs, pre-veneered SSCs, zirconia crowns, and luting cements used were resin cement, glass ionomer cement (GIC), resin-modified GIC (RMGIC)	36	Posteriors	Zirconia crowns that were cemented with resin cement showed accurate fitting internally.

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Author (year)	*Type of study*	*Follow-up*	*Crowns used*	*No. of crowns*	*Anterior/posterior*	*Conclusion*
						With regard to marginal fit, no significant difference was observed between zirconia crowns, pre-veneered SSCs, and SSCs regardless of the luting cement used (resin cement, RMGIC, or GIC).
Al-Haj Ali and Farah (2018)[41]	*In vitro* study	–	Preformed metal crowns (PMCs), pre-veneered PMCs, zirconia crowns	36	Posteriors	Zirconia crowns showed significantly worse microleakage than that in pre-veneered PMCs and PMCs. When microleakage is concerned, pre-veneered PMCs seem to be an esthetic alternative to PMCs and zirconia crowns.
Jing et al. (2019)[42]	*In vitro* study	–	EZCrown	75	Posteriors	The zirconia crown retention force is closely related to the occlusocervical heights (OCH). OCH of 2 mm is crucial for prefabricated zirconia crown retention.

in vitro study. In case of Kinder crowns, higher fracture loads were obtained after the chewing stimulation, due to the phase transformation from the metastable tetragonal state to the stable monoclinic form that was caused by the application of energy to the zirconia crowns during the chewing simulation. Monoclinic zirconia materials are known to show higher flexural strength than tetragonal materials.[25]

Zirconia crowns are also found to prevent the *Streptococcus mutans* adhesion onto its surface, and diminished plaque collection around the crown and less irritation of the encompassing gingiva when contrasted with SSCs.[26] Hence, it could likewise help in lessening the general microbial thickness, in this way decreasing the caries risk in the long-term.[26] The accumulation of biofilm in SSCs can be because of the surface irregularities made by trimming, crimping, and cutting, which thus propagate periodontal disease,[27] while the preformed zirconia crowns were not balanced along these lines ensuring the surface completion to forestall microbial and plaque adhesion. Taran et al. researched the periodontal health related with SSC and zirconia crowns among 7–8-year-old youngsters and announced zirconia crowns to have better periodontal health and less plaque retention.[28]

Another concern for using zirconia crown is regarding the cementation. Etching and bonding are not possible in zirconia due to the lack of silicone in glass ceramic. Sandblasting has reported to cause microcracks in zirconia; etching with phosphoric acid or hydrofluoric acid was shown to have no impact on complete retention of restoration. Conventional or self-adhesive resin cements have been recommended as luting agents for zirconia crowns.[14,29]

In a study of pediatric dental specialist's treatment choices and therapeutic modalities, about 65% of the dental specialists have announced that they never considered pre-veneered or zirconia crowns as restorative choice for decayed front deciduous teeth. The investigation suggests that the pre-veneered or zirconia crowns are essentially underutilized by the general dentists while the utilization of hardened steel crowns is by all accounts still of value.[30] This finding was in par with the examination done in Indiana by Kowolik et al.[31] Correspondingly, Wilson et al. had likewise detailed a similar pattern in the contemporary dental practice in the UK, where authors recommended that the pediatric dental specialists are still in the early phase with respect to the utilization of esthetic crowns and it is maybe of worry that pediatric dental specialists are not keen on proceeding with training courses about this subject.[32]

In a study where the esthetic concerns and agreeableness of treatment modalities in deciduous teeth of youngsters and their folks were compared, Zirconia crowns seemed, by all accounts, to be the most worthy full-coverage restoration for deciduous teeth among the kids and their parents.[33] This was in accordance with the study by Holsinger et al.[34]

Nonetheless, the utilization of prefabricated zirconia crowns is not liberated from downsides and restrictions, as proposed by Diener et al. The amount of tooth reduction is more in Zirconia crowns; increased hardness of these crowns can cause wear of the antagonist teeth. Zirconia is a polymorphic material and it requires the addition of stabilizers, similar to yttrium and magnesium oxide, for forestalling the difference in tetragonal/cubic stages to the monoclinic stage at room temperature. Any variation in the amount and the type of phase stabilizers used, there will be changes affecting the phase consistency and the crystal structure, which in turn can impact the mechanical, thermal, and electrical properties. Also, the process of manufacturing can have influence

on the material structure and surface qualities by creating cracks, adjusting harshness, and the grain size, which thusly impact the compressive quality, fracture toughness, hardness, esthetics, plaque retention, and bonding strength of the crown. Henceforth, zirconia-made pediatric crowns that contrast in compound blend microstructure and creation parameters may show a wide scope of mechanical properties and definitely a modified clinical behavior.[12]

Conclusion

With the available evidence in the literature, it can be concluded that zirconia crowns can be used as an effective full-coverage restoration for the primary teeth.

Clinical Significance

Since the number of review on zirconia crowns and their use in pediatric dentistry are few, the current review was done to make a stock of the current literature to sum up the data on preparation guidelines, clinical execution, and to analyze and discuss about the difficulties encountered, consequently helping the clinicians with supportive thoughts in the dynamic cycle of when and where the utilization of zirconia crowns is suitable in children.

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