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ZIRCONIA IN PEDIATRIC DENTISTRY – A REVIEW

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ABSTRACT

Esthetic treatment of severely decayed primary teeth is one of the greatest challenges for pediatric dentist. There are different types of restorations for complete crown coverage. These restoration technique includes stainless steel crowns, polycarboate crown, acid etch crown etc. Each of these techniques presents technical, functional or esthetic compromises that complicate their efficient and effective usage. Due to a increasing in esthetic and concerns about toxic and allergic reactions to certain alloys, zirconia was proposed as a new ceramic material in the later part of 20th century. It has become a popular alternative to alumina as biomaterial and is being used in dental applications. This article presents a brief history, properties, dental applications and tooth preparation of zirconia crown. Subject Area: dentistry Keywords: stainless steel crown, zirconia, dental caries, primary molars

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INTRODUCTION

Early childhood caries (ECC) is a protracted multifactorial disorder which continues to be dominant in children, especially in the families with low socioeconomic class.[1] ECC is construed as "the existence of one or more tooth decays (noncavitated or cavitated lesions), removed (due to caries), or filled tooth surfaces in any primary dentition of children under the age of 6 years."[2] ECC remains to be a global health problem, involving the foremost carious lesion of the primary maxillary incisors, then the mandibular, maxillary first primary molars and mandibular cuspids.[3] Stainless steel crowns (SSCs) has been utilized for the restoration of primary dentition affected by caries, decalcification in the neck of the tooth, and developmental defects (e.g., hypoplasia, hypo calcification). It is also used when the downfall of further accessible restorative supplies is more probable (e.g., interproximal caries ranging farther than line angles, children with bruxism). Moreover, next to pulpotomy or pulpectomy, SSC is used in the restoration of a primary tooth which will be exploited as an abutment to maintain space or to be used as interposed rehabilitation of severed teeth.[4] Stainless steel crowns were easily available as preformed, pretrimmed and pre contoured crowns with wide range of sizes and with proven clinical efficiency.[5]

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Stainless steel crowns, introduced by "Rocky Mountain" company were later improved by various manufacturers and they were used in restoring multi surface caries of primary and young permanent dentition, as post endodontic restoration, abutment for space maintainer and as preventive restoration for special children. Literature evidence exposes the superiority of stainless steel crowns over conventional restorations even when used as a preventive strategy for children with medical or dental developmental disability. The only disadvantage of SSC was its unesthetic appearance.[1,6] The need to meet the demand for esthetic restorations led to the introduction of open faced stainless steel crowns, pre veneered crowns, polycarboxylate crowns and strip crowns. Each of these full coronal restorations has their own advantage and disadvantage. The technological advances in techniques and material science led to the evolution of preformed Zirconia crowns for primary teeth, so as to fulfill the esthetic demands, at the same time promise good durability. Zircon has been known as a gem since ancient times. The name zirconium comes from the Arabic "*Zargun*" (golden in color) which in turn comes from the two Persian words "*Zar*" (Gold) and "*Gun*" (Color).[7] Zirconia is a crystalline dioxide of zirconium. Zirconium oxide was first used for medical purposes in 1969 for orthopedic application. It was proposed as a new material for hip head replacement instead of titanium or alumina prostheses.[8] Zirconia crowns are known as "Ceramic Steel" as it provides strength close to available metal crowns as well as colour similar to that of natural teeth.

Pediatric zirconia crowns were introduced by EZ-pedo and became commercially available in 2008. Later preformed zirconia crowns were popularized by companies like Nusmile, Kinderkrowns, Cheng crowns, Signature crowns and many more .These preformed crowns differed with respect to size, shape, shade and pattern of retention component.[9] Zirconia is organized in three different patterns: monoclinic (M), tetragonal (T), and cubic (C). Pure zirconia is monoclinic at room temperature and remains stable up to 1170°C. Above this temperature, it transforms into tetragonal and then into cubic phase that exists up to the melting point at 2370°C. During cooling, the tetragonal phase transforms back to monoclinic in a temperature ranging from 100°C to 1070°C.[7]

Mechanical properties of zirconia

MECHANICAL PROPERTIES	AMOUNT
Density	6.05 g/cm3
Hardness	1200 HV
Bend strength	900-1200 MPa
Compressive strength	2000 MPa
Fracture toughness	7-10 MPam½
Young's modulus	210 GPa
Thermal expansion coefficient	11x10-6 1/K

Zirconia has a unique ability to resist crack propagation by being able to transform from one crystalline phase to another, and the resultant volume increase stops the crack and prevents it from propagating.[10] Zirconia has demonstrated high wear resistance, excellent biocompatibility, and superior corrosion resistant. Three type of zirconia are currently used in dentistry; these are yttria stabilized tetragonal zirconia polycrystal (Y-TZP), magnesia partially stabilized zirconia and zirconia toughened alumina. Y-TZP is a monolithic zirconia that consists of equiaxed partially stabilized tetragonal grains.[7] Because of the superior mechanical properties of Y-TZP ceramics, these materials have a wide range of clinical applications.

Dental application of zirconia

Zirconia-Based Dental Posts: The requirement for more esthetic posts, especially under all ceramic restorations, has started the development of new post materials. In situations where all-ceramic restorations are used for restoring anterior teeth, metal posts may result in unfavorable esthetic results, such as a grey discoloration of translucent all-ceramic crowns and the surrounding gingival margin.[11]Additionally, corrosive reactions with prefabricated posts may cause complications involving the surrounding tissues and oral environment, including a metallic taste, oral burning, sensitization, oral pain, and other reactions. These concerns have led to the development of white or translucent posts made of zirconia.[12]
Zirconia posts are available as smooth, tapered and parallel, or tapering at apex and parallel at the coronal aspect. They are rounded at the apical zenith to minimize stress concentration at the root apex. Other varieties include polyester with 65% zirconium fibers, with lower Young's modulus and stiffness compared with pure zirconia, but without compromising the advantageous light transmission properties. Zirconia posts which can be used with both direct and indirect techniques, are highly biocompatible, radiopaque, and have excellent light transmission *via* both the root and coronal restoration.[13] Kakehashi *et al*. experimented with zirconia ceramic post clinically and reported that the zirconia post showed a high success rate.[14] Likewise, Paul and Werder investigated zirconia posts and observed good clinical success of zirconia posts with direct composite cores after a mean clinical service of 4.7 years.[15]The mechanical properties of zirconia posts were tested in *in vitro* study by Kwiatkowski and Geller. Their results demonstrated that the zirconia posts had higher strength compared to those reported for other all ceramic post and cores.[16] Zirconia posts also offer possible advantages with respect to esthetics and biocompatibility[17], but have some limitations. They are stiff without any ductility; therefore, difficulties can be encountered when they are in small sizes and when retreatment is necessary.[18]

Zirconia-Based Crown and Bridge: The fabrication of zirconia frameworks of either presintered or highly isostatic pressed zirconia for crown and bridge has also been employed. Zirconia frameworks offer new perspectives in metal free fixed partial dentures and single tooth reconstructions because of zirconium's high flexural strength of more than 900 MPa and showed good first clinical results.[19]

Zirconia-Based Implant Abutments: As a result of utilizing the zirconia ceramics for the fabrication of tooth-supported restorations, this encouraged the clinicians to extend its application for implant-supported restorations.

Utilizing zirconia as implant-supported restorations is due to the higher toughness and the lower modulus of elasticity of zirconia. In stabilized and transformation toughened forms,zirconia provides some advantages over alumina in order to solve the problem of alumina brittleness and the consequent potential failure of implants.[20] Yildirim *et al*. compared in their *in vivo* study 30 zirconia abutments with 51 alumina abutments. They found cumulative survival rates of 100% and 98.1% for each group of implant abutments respectively for an observation period of 28 months.[21]

Zirconia-Based Esthetic Orthodontic Brackets: zirconia has also been applied for the fabrication of esthetic orthodontic brackets.[22] Polycrystalline zirconia brackets, which reportedly have the greatest toughness amongst all ceramics, have been offered as an alternative to alumina ceramic brackets.[23]They are cheaper than the monocrystalline alumina ceramic brackets but they are very opaque and can exhibit intrinsic colors making them less aesthetic. Good sliding properties have been reported with both stainless steel and nickel-titanium archwires along with reduced plaque adhesion, clinically acceptable bond strengths and bond failure loci at the bracket/adhesive interface.[24]

- Tooth with large carious lesion.
- Teeth with hypoplastic defects or with development anomalies such as dentinogenesis or amelogenesis imperfect.
- Teeth that have undergone pulp therapy.
- Fractured teeth
- Extensive tooth loss due to bruxism, attrition or abrasion.
- Patient allergic to nickel and contraindicated for stainless steel crowns.

Contraindication

- Crowded dentition
- Uncooperative child

- Subgingival soft caries
- If a space maintainer or orthodontic appliance requires soldering to be done on crown

Ageing of zirconia: Under certain manufacturing conditions or more severe environmental conditions of moisture and stress, the resulting zirconia may transform more aggressively to the monoclinic phase with catastrophic results.

All transitions which occurred between the different crystalline reticulations are due to the stress applied on the zirconia surface, and this produces a volumetric change in the crystal. Such a “high metastability” is obviously undesirable for medical implants. This mechanical property degradation in zirconia, due to the progressive spontaneous transformation of the metastable tetragonal phase into the monoclinic phase, is known as “ageing” of the material.[25-27] A slow transformation as mentioned previously occurs when Y-TZP comes in contact with water or vapor[26], body fluid or during steam sterilization[7], which leads to surface damage. The increase in monoclinic phase leads to a reduction in strength, toughness and density, followed by micro and macro cracking of the material.[28] Surface degradation of the material during low temperature aging involves roughening, increased wear and microcracking, grain pullout, generation of particle debris, and possible premature failure.[29] Surface elevations take place most likely because of the more voluminous M-phase transformed particles.[27]Aging behavior is related to the differences in equilibrium within the microstructural parameters, such as yttrium concentration and distribution, grain size, flaw population, duration of exposure to aging medium, loading of the ceramic restoration, and manufacturing processes. Reduction in grain size and/or increase in concentration of stabilizing oxides can reduce the transformation rate. However, reducing the size of grains too much may lead to the loss of “metastability”, and increasing the concentration of stabilizing oxide above 3.5 mol% may allow the nucleation of significant amounts of the stable cubic phase.[30-31]

Different company zirconia crowns

Nusmile Zr : these are scientifically developed using CT and digital scan of natural primary teeth. they have 0.2mm margins and in two shades(light and extralight). There are 0-6 sizes for upper and lower canines whereas lower incisors have 1-4 universal sizes. In posteriors, there are 1-7 sizes. It also provided with NuSimle Try-In crown to check fittig prior to final cementation. (zirconia crowns not contaminated with blood or saliva have better adhesion to cement and to solve this problem NuSmile came up with the try-in pink crown). NuSmile Zirconia crowns have improved marginal adoption to the tooth and are meager at the cervical crevice than the other brands. This results in lower likability of cement washout, reducing the possibility of cementation failure or subsequent decay.[1]

Kinder Krowns Zr: It has internal retention system(retention bands) which locks restoration after cementation. Fine feathered margin of zirconia kinder krown makes the emergence profile for the crown as natural. It is available in two sizes- mid size and regular size. Mid sizes are designed to alleviate seating issues in situations when placing crowns back to back or when patients have experienced major space loss. The mid-sized crowns have same buccolingual width, but the mesio-distal has been reduced to allow for easier postion placement. They make LP-less prep design that requires less reduction and time to place. The central and lateral have 1-6 sizes. Canines have 1-6 regular sizes and 0.5-5.5 mid sizes. Posteriors have 2-7 regular sizes and 1.5-6.5 mid sizes.

EZ Pedo crowns: They have flat-fit interproximal contours making side by side placement with zirconia easier. It comes with the patented retention technology, Zir-Lock Ultra, i.e. retentive grooves which extend all the way to crown margins, preventing cement washout, prevents entry of harmful bacteria and also provides two times more surface area for bonding.

Cheng Crowns: It features a simulated crimp to allow for better retention. It has a knife edge (0.2) crimped margins which gives a more natural emergence profile while preserving ease of crown seating. It has a satin finish on the facial and a mirror like quality on the lingual and margins. Company makes 1-6 sizes in both anteriors and posteriors with two shades of light and extra light.

Kids-e-Crown: The posterior crowns have inner flat occlusal table with uniform axial walls. There are micromechanical boxes for retention. The wall thickness is 0.3 mm and margins are 0.2 mm. The sizes for anteriors are 0-5 and posteriors there are five regular sizes 2-6 and three narrow sizes 3-5. The narrow sizes are mid-sizes with broader buccolingual dimension for proximal lesions and space loss caes. The labeling of the crowns is permanently embossed inside the crown.

Signature crown: It has 0.2 mm feather edge margin and 0.5 mm overall thickness. Posterior crowns have flat distal proximal wall of primary first molar and mesial flat proximal wall of primary second molar with no narrow crowns. In anteriors, both universal contoured and left/right side options are available. There are 1-6 posterior and 1-4 anterior sizes with no space loss crowns.

Tooth preparation: Tooth preparation and cementation procedure are important clinical steps in a crown placement. The presence of adequate clearance, proper angulations, and visible knife edge finish lines helps to preserve gingival health and less plaque accumulation. Adequate preparation of the tooth will significantly improve esthetics, crown fit reduces chances of veneer fracture and saves chair time. The tooth should be prepared to fit the crown so that the crown fits the tooth passively without using pressure.[32]

ANTERIOR TECHNIQUE

Crown selection: Select appropriate size of crown measuring mesiodistal width.

Incisal reduction: Reduce 1.5-2mm incisally using donut shape bur following the incisal plane.

Supragingival reduction: Make a chamfer finish line of 0.5-1mm on all four sides of crown equigingival using chamfer bur.

Supragingival reduction: Using a taper bur, remove the chamfer finish line going 1-2 mm subgingival making a feather edge or no finish line.

Check fit and bleeding control: Check for passive fit of selected crown. Control bleeding using pressure or hemostat. Clean the crown under tap water and with alcohol to remove blood and saliva.

Posterior technique

Crown selection: The selection of the appropriate crown size was performed prior to the tooth preparation. This is done by holding a crown up to their existing tooth or considered the mesiodistal dimension and selected the crown size to be used based on the original size of the tooth. Alternatively, a digital x-ray system, that may pre-size the crown by taking measurements in software and match patients interproximal width to the corresponding crown size.Local anaesthesia was applied prior to the tooth preparation.

Occlusal preparation: Using the marginal ridge of the adjacent teeth as a reference point, 1.5–2 mm of occlusal reduction was performed. An adequate occlusal reduction is extremely important for the proper fit and placement of paediatric zirconia crowns. The final occlusal plane of the seated paediatric zirconia crown is determined by the amount of occlusal reduction. For occlusal reduction, it is recommend using a coarse grit wheel diamond bur (1.2mm).

Buccal-Lingual Reduction: Reduce buccal-lingually approximately 1-1.5 mm using a flame-shaped diamond bur. During buccal lingual reduction, keep the bur parallel to the tooth. Keeping the bur parallel to the tooth ensures consistent reduction from the occlusal down to the gingival tissue.

Interproximal Reduction: Next reduce interproximally 1mm using a flame shaped diamond bur, such as a .368 or a .330 tapered carbide. During interproximal reduction, keep the bur parallel to the tooth and remain supragingival. This technique will reduce the likelihood of contacting the pulp.

Feather Margin: Using a flame-shaped diamond bur reduce subgingivally 1-2mm, ending with a feathered margin. Often there is a remaining band of tooth structure, just below the tissue - removing that tooth structure is the key to achieving a passive fit.

Trial Fitting: The most important key to remember when placing Zirconia is that a passive fit is required. Zirconia are solid ceramic and do not flex. If the crown won't go into place without resistance, you will need to reduce more tooth structure. The appropriately sized crown will seat passively and subgingivally 1-2 mm and should not alter the gingival tissue.

Cementation: The tooth and the crown were cleaned of all blood residues. Haemostasis of the gingiva was obtained via pressure applied with a finger. A glass ionomer cement (Fuji One PLUS, GC, Louvain, Belgium) was used for the cementation.

Advantages: They are highly esthetic, with greater durability than composite strip crowns and preveered crowns. Highly biocompactible and as strong as steel. High acceptance by patients and parents. They are not as technique sensitive as composite strip crowns, as the fabricated crown is cemented rather than bonding. Zirconia crowns will not chip. Do not discolor and break down over time like resin strip crowns. Can be autoclaved without changes in property.[33]

Disadvantages: They are thicker than other crowns, therefore greater tooth reduction is required. Subgimgival preparation leads to bleeding, which can hamper bonding strength of luting cement. Brittle- can fracture if not handled properly. High cost as more number of sizes required. Abrasion of opposite natural tooth if not polished properly. Shade options are limited.[33] Crown not recommended for children who are fearful and unable to cooperate for longer procedures. It is difficult to adjust a zirconia crown because it is ceramic and cannot be trimmed with scissors like a traditional SSC, it is necessary to use a high speed, fine diamond burs with lots of water because excessive heat could cause fractures in the crown's ceramic structure. Occlusal and interproximal adjustments are not recommended, it will remove the crown's glaze and possibly create a weak area of thin ceramic. zirconia crowns fit passively because they are made of solid zirconia and do not flex, attempt to sit with force will result in fracture and adjustment with bur result in microfracture.[34-35]

Cements used for zirconia crowns: There is a widely choice of materials for cementing metal-free restorations. These include: zinc phosphate, conventional and modified glass-ionomer cements, resin cements and self-adhesive cements Shear bond strength of 11 cements on zirconia was evaluated by Piwowarczyk et al.[36] Results indicated that zinc phosphate and both conventional and modified glass-ionomer cements aren't able to form a lasting bond with zirconia; only Rely X Unicem (resin cement) and Panavia F2.0 (resin cement containing MDP monomer) show good results even after aging. From study of Luthy et al.[37] was seen that bond strength of glass-ionomer cements and conventional Bis-GMA-based composites is significantly lower, especially after aging by thermocycling. Only Rely X Unicem and Panavia F2.1 withstands such procedure, with the latter achieves high bond strength. Zinc phosphate cements, glass-ionomer cements and conventional Bis-GMA-based cements have shown a low adhesion. Resin cements containing esteric organophosphate monomer (MDP) have shown in different studies a higher capacity of adhesion and stability after aging process; this is attributed to the capacity to bind metal oxides such as zirconium oxide. A study done by Maha Moussa Azab et al stated Packable glass ionomer is more retentive than bio-active cement when used for cementing zirconia pediatric crowns. Posterior zirconia pediatric crowns have high fracture resistance after 36 months clinical performance, irrespective of luting cement. Luting cement for zirconia pediatric crowns has no apparent effect on gingival condition around crowns.

Cleaning methods for zirconia following salivary contamination: A recentmeta-analysis concluded that optimal bondsto zirconia were obtained by using resin-based cements.[38] A practical obstacle encountered while bonding to zirconia restorations, however, is that salivary contamination during try-in of the restoration can weaken the bond to the resin cement.[39] Recent studies have suggested that applying phosphoric acid to surfaces of zirconia, however, leaves a phosphorous residue that impairs the bond strength to resin cement.[40] Other cleaning methods, such aswashing with an organic solvent or alcohol, have been reported in the literature as largely ineffective.[41] A relatively novel and commercially available product (Ivoclean; Ivoclar Vivadent, Schaan, Leichtenstein) composed of a hyper-saturated solution of zirconia particles has been developed to remove contaminants. To improve the resin/zirconia bond, primers containing phosphate monomers, such as 10-methacryloyloxydecyl dihydrogen phosphate (MDP), are often used.[42] MDP is a bifunctional monomer with a phosphate-based functional end that bonds to zirconia and a methacrylate-based functional end that bonds to resin cements.[43]

Conclusion

Although clinical long-term evaluations are a critical requirement to conclude that zirconia pediatric crowns have good reliability. It is expected that in the near future, prefabricated zirconia crowns could be an easy, restorative option to traditional stainless steel and composite strip crowns due to their unparalleled advantages. Zirconia crowns offer high-end esthetics, superior durability, and easy placement compared to composite restorations and strip crowns.

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