DOI: 10.21608/adjalexu.2023.249332.1446

A DENTAL MATERIALS APPROACH TO PEDIATRIC DENTAL FULL COVERAGE – A REVIEW

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ABSTRACT

BACKGROUND: Dental caries is considered the most prevalent oral disease, especially among children. Full coverage is indicated in multi-surface carious lesions, large interproximal lesions, teeth with hypoplastic defects, or severe discolorations, and cases with very poor oral hygiene and high caries risk. Pulp therapy procedures should be followed by the addition of a full coverage restoration to provide support to the tooth structure. There are various materials and methods of fabrication of full coverage primary crowns.

OBJECTIVES: This review classifies pediatric crowns according to the method of fabrication. Each category is then subclassified according to material.

CONCLUSION: The most suitable crown should be chosen based on the patient cooperation, esthetic demands, extent of decay, amount of tooth structure as well as moisture control and ability of bonding to the tooth.

KEYWORDS: Pediatric dentistry, Dental pediatric crowns, SSC, Zirconia crowns, 3D Printing, CAD-CAM.

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INTRODUCTION

Dental caries is considered the most prevalent oral disease, especially among children. Children suffer from functional and esthetic problems as a result of tooth decay which may extend to the dental pulp causing irreversible pulpitis or periapical inflammation. Extensive tooth damage and loss of tooth structure can lead to premature tooth extraction which is the main cause of malocclusion and malalignment of the primary as well as the permanent teeth (1).

Full coverage is indicated in multi-surface carious lesions, large interproximal lesions, teeth with hypoplastic defects, or severe discolorations, and cases with very poor oral hygiene and high caries risk. Pulpotomised or pulpectomised primary and permanent teeth help preserve tooth structure and prevent its premature loss as a result of extensive decay; these procedures should be followed by the addition of a full coverage restoration to provide support to the tooth structure after endodontic treatment to increase the durability of the restoration. The most common full coverage restoration is the stainless-steel crown (SSC) which is a preformed restoration that comes in different sizes and is characterized by ease of placement and good marginal adaptation. Due to its unpleasant appearance owing to its metallic nature, it is used only for posterior primary teeth (2).

Anterior decayed teeth are very fragile, and their loss leads to esthetic and phonetic problems for the child. The emergence of esthetic tooth-colored crowns enabled the restoration of the esthetics of anterior teeth and prevented the need to extract and replace the teeth with partial dentures or space maintainers. Polymeric as well as ceramic materials are used to provide not only durable but also esthetically pleasing restorations (3).

In this review, pediatric crowns are classified according to the method of fabrication which could be either: prefabricated (ready-made), modified prefabricated (ready-made crowns with a possibility of customization by adding the desired facing material) and custom made. Each category is then subclassified according to the type of material which could be metal, ceramic, polymer, composite, or combination (Figure 1).

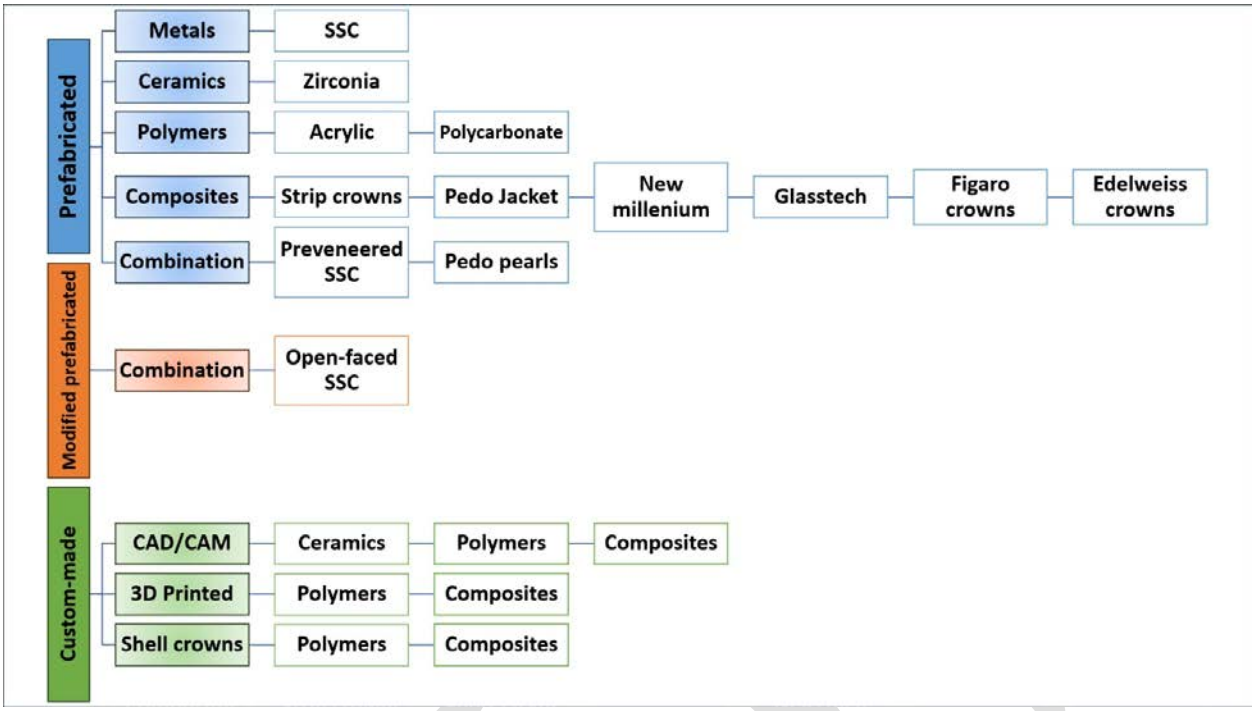

Figure 1: A diagram showing the classification of pediatric crowns according to method of fabrication.

Types of Pediatric dental crowns

1) Prefabricated Pediatric Crowns

Prefabricated pediatric crowns have been used for the last five decades. They are available in different materials including metallic, ceramic, polymeric, and composite-based crowns. These crowns can be luted or bonded to the tooth substrate depending on the crown material. In general, preformed crowns are indicated to restore pulpal treated, extensively carious, or congenitally deformed teeth in order to provide a long-term well-fit restoration (1). The main advantage of preformed crowns is that they are considered an effective treatment option performed in only one visit within a short operational time (4). In this review article, preformed crowns are classified into the following categories: metallic, ceramic, polymeric, and composite-based and combination crowns.

A) Metals

Preformed metal crowns (PMCs) are classified into two types based on their composition. The first type is the stainless steel crowns (SSCs), whereas the second type is the nickel-chromium (Ni-Cr) crowns (4). Stainless steel crowns are composed of 67% iron, 18% chromium, 8% nickel, while Nickel-chromium crowns are composed of a Nickel Chrome alloy (70% nickel, 15% chromium,10% iron). The SSCs were first used in dentistry by Humphrey and Engel in 1950.

These PMCs are luted to the tooth after choosing the correct crown size. They are supplied in three types. The untrimmed noncontoured type requires adaptation due to a lack of trimming and contouring. The second form is the pre-trimmed crowns which are festooned to mimic the gingival line. However, they still need to be contoured. The last type is the pre-contoured crowns which are contoured and festooned showing the best simulation of the anatomical form. These metal crowns can be crimped and contoured to increase retention to the tooth structure using specific pliers.

The introduction of nickel-chromium crowns led to overcoming some major drawbacks seen in the initial SSCs as Ni-Cr crowns are properly formed and defect-resistant. Moreover, they do not often need trimming due to enhanced anatomical form. However, they must be adjusted to increase their adaptability, but with fewer steps (5). PMCs are durable restorations with long-term survival rate and easy placement technique (4, 6, 7). However, these crowns have poor aesthetics due to the metal color. Besides this, they cannot be placed on teeth which are partly erupted. Another challenge is crown drifting towards the immensely destructed wall or ill-fitted margins when the crowns are poorly adapted (1, 4).

Preformed metal crowns are used in both primary and permanent molars. In primary molars, these crowns are an indicated treatment option for teeth with multi-surface carious lesions, pulpal-treated teeth, patients with high caries index or those who suffer from bruxism, teeth with developmental anomalies, and as an abutment to receive a space

maintainer (1, 4, 8, 9). In permanent teeth, PMCs can be used as a temporary restoration in case of fractured teeth or teeth which need to be fully covered until a final restoration can be placed. They also can be used to cover teeth with developmental malformation or abnormalities, or when the patient cannot afford a more expensive treatment option (4). Nevertheless, PMCs are contraindicated for patients with nickel allergy, or uncooperative patients. Moreover, they cannot be placed on teeth which are about to exfoliate or teeth displaying resorption of more than half of the root (8).

B) Ceramics

Zirconia is a bio ceramic material that has been used in pediatric dentistry as a restoration material since 2010. Zirconia, also known as 'ceramic steel', is polycrystalline zirconium dioxide. It is a polymorph structure with three different faces which are Monoclinic, Tetragonal and Cubic face. It is used to make prefabricated biocompatible crowns with different sizes and shades to be used for both anterior and posterior primary teeth. The unique feature of zirconia is that it is an aesthetic restoration for primary teeth. Zirconia pediatric crowns may present in different forms based on the stabilizer used which are yttria-stabilized tetragonal polycrystal (Y-TZP), magnesia-partially stabilized zirconia, and zirconia-toughened alumina (1, 10). There are several commercial brands of zirconia crown available in the market including Ez-Pedo, NuSmile ZR, and Kinder Crowns Zirconia (11).

Zirconia crowns are a good substitute for Ni-Cr allergic patients where the metallic restoration is contraindicated. For adequate seating of zirconia crown, subgingival buccal reduction with complete removal of the cingulum area is required (4). The retention of zirconia crowns is based on the bond strength of the luting cement between the tooth and the restoration, which is dependent on the cement used. There are different types of cements that can be used as pure Glass Ionomer Cement (GIC) which bonds to tooth structure but does not bond to zirconia. However, resin-modified glass ionomer cement (RMGIC) or resin cement, in which the resin can bond to the inner surface of the zirconia, are recommended for cementation of the these crowns (12).

Zirconia crowns are very strong and hard restorations with high fracture resistance. They are highly esthetic restorations with multiple tooth shades and translucencies. No allergic reactions or toxicity occur as a result of their usage and they preserve the healthy gum owing to knife edge cervical margin (1, 2). Previous studies showed that plaque and gingival indices are very low around zirconia crowns due to their highly finished and polished margins that inhibit the plaque accumulation with minimum risk of developing secondary caries (13). Zirconia crowns can also resist wear and corrosion. They are durable restorations with high fracture toughness which can resist crack propagation due to transformation in the crystalline phases (11). On the contrary, their margins are difficult to modify and they are also abrasive for opposing natural dentition (1). These crowns should fit passively to the prepared tooth structure which necessitates over preparation. Any active pressure during try-in leads to crown fracture owing to its brittle nature.

C) Polymers

1- Acrylic

Pediatric acrylic crowns are tooth-colored restorations designed specifically for primary anterior teeth. They are composed of biocompatible heat-cured acrylic resin, that is free of bisphenol-A (BPA). The dough-like acrylic resin is placed into a mold, and heat and pressure are applied to the mold to initiate the curing process. Acrylic crowns are available in various sizes, shapes, and shades to simulate the anatomy of natural teeth. These crowns provide full coverage and offer numerous advantages in terms of aesthetics, durability, and ease of placement. Moreover, they offer good marginal adaptation and retention. This makes them very useful particularly in situations where there is insufficient tooth structure or space loss. With their ability to withstand biting forces and resist wear, acrylic crowns provide long-term solutions for restoring primary teeth. Additionally, they offer insulation against temperature changes, reducing tooth sensitivity. They are cemented on the prepared tooth structure. The GIC and RMGIC are commonly used. Unlike some other restorative materials, pediatric acrylic crowns are not easily repairable. If a crown becomes fractured or damaged, replacement is usually required, which can be a disadvantage in terms of time and cost (3).

2- Polycarbonate

Polycarbonate crowns are prefabricated, thermoplastic acrylic crowns made of aromatic polyesters of carbonic acids. They were fabricated to restore the anterior deciduous teeth and were first described by Mink J.W in 1973. Compared with prefabricated heat-molded acrylic crowns, polycarbonate crowns are thinner, more adjustable, more easily adapted, and more flexible. They are indicated as a full coverage restoration for deciduous maxillary anterior teeth with multiple carious lesions, and for fractured, malformed, or discolored teeth. Therefore, polycarbonate crowns can be a good treatment option for anterior pediatric teeth provided that the case is properly selected as reported by Venkataraghavan et al. (14). However, owing to their inability to *withstand abrasion, or* frequent dislodgement*, these crowns are*

contraindicated to be used in extensively destroyed teeth, or in patients with bruxism, or in those with deep overbite (1, 4).

D) Composite-resin

1- Strip crowns

Prefabricated strip crowns are celluloid forms that were introduced by Webber in 1979 (3). They have been the treatment of choice for many dental clinicians for primary incisors, due to their pleasant aesthetics, low price, less chair-side period, and repairability in case of fracture (2, 3). A good aesthetic is provided by adjusting the suitably fitted crown by trimming it and choosing the correct composite shade. The composite resin is placed inside the crown form and then the form is seated on the tooth and cured. Then, the form is removed leaving a smooth polished surface (1, 3). For reaching a satisfying anterior restoration, the sandwich technique can be used. For this, RMGIC can be used to substitute for dentin together with the resin composite (3). Also, masking materials can be added to this combo if there is arrested caries to hide its color (15). Strip crowns are indicated for extensively carious, pulpal-treated, or fractured anterior primary teeth. Besides these indications, they can be used to treat developmental defects and discolored teeth. Despite this, it is a technique-sensitive process requiring a moisture-free field, therefore blood from inflamed gingiva can hinder proper bonding together with discoloring the composite. Moreover, adequate tooth structure should be preserved for bonding and retention. This explains why it is contraindicated to use strip crowns when there is extensive tooth loss, periodontal disease, or even deep overbite (1, 4)

2- Pedo Jacket crowns

Jacket crowns are used in restoring primary upper anterior teeth particularly in the pre-cooperative age. It is much like strip crowns but with few differences regarding the material. These crowns are made of tooth-colored flexible co-polyesters which are bonded to the teeth (1-4). Like strip crowns, the crown is filled with resin and bonded to the tooth. However, unlike strip crowns, jacket crowns are retained on tooth after resin curing (1, 2). Marginal adjustment can be done by removing extras of resin before curing and so polishing is not obligatory. These crowns are cost effective and require minimal tooth preparation (2). However, being made of co-polyester, crown trimming, and adjustments have to be done by scissors and not by handpiece bur to avoid crown melting (4). Besides this, the crowns are supplied in only one size and one light shade making it challenging to match the natural adjacent teeth shade. Moreover, color change, wear under heavy occlusion forces and frequent dislodgement are usual problems associated with this crown type (3).

3- New Millennium

New Millennium crowns are preformed crowns that can be considered modifications of strip and pedo jacket crowns. However, these crowns are fabricated using laboratory-enhanced composite resin (2, 3). These crowns are supplied for both anteriors and molars and are bonded to teeth after the form is filled with resin. The crowns have pleasant aesthetics and can be easily trimmed then finished with burs. On the other hand, these crowns have some drawbacks including the high cost and brittleness. The procedure is also technique sensitive requiring proper tooth isolation and bleeding control to ensure a successful bonding to the tooth substrate (2-4). These crowns are a good treatment option for restoring teeth with multi-surface lesions, incisal fractures, or discoloration of incisors and congenital or developmental teeth defects. Nevertheless, they cannot be placed if a dry clean field cannot be obtained, or when there is a massive tooth destruction with not enough sound structure is available for bonding (1, 4)

4- Glasstech

Glasstech crowns, also called organic crowns, are preformed composite based crowns which are made up of artglass and supplied in six sizes. The artglass is a three-dimensional crosslinked polymer glass (1, 3). These crowns have the advantages of color stability, durability, and superior esthetics compared to strip crowns due to the presence of micro-glass fillers and silica. Moreover, they are plaque resistant and wear friendly to opposing teeth. By having the previous advantages, artglass crowns have combined the advantages of both porcelain esthetic and durability with the composite repairability and bonding ability (2, 3). However, these crowns display some drawbacks as they are supplied in only one shade and crown failure may occur due to inadequate bonding to tooth structure (3).

5- Figaro crowns

Another recent type of composite based crowns is the figaro crowns which were introduced to the dental markets in 2018 (16). There are 5 different sizes available for each tooth (3). These crowns are made up of resin composite matrix inside which quartz filaments, glass fibers or aramid carbon sheets are embedded. The presence of these reinforcing fillers has greatly improved the crown strength making it comparable to that of the SSC as claimed by the company (3, 16, 17). Subramanian et al. reported that there was no significant difference regarding the retention of SSCs and Figaro crowns at 9 months and 1 year follow up which make these crowns a practically more esthetic alternative to SSCs (17). Besides the aesthetics, these crowns display other

advantages including being metal free and autoclavable. They are also designed depending on the flex-fit technology which enables them to be placed with minimal preparation thus maintaining more sound tooth structure (16). Despite the mentioned advantages, Figaro crowns cannot be readily visible on radiographs and cannot be crimped unlike the metallic crowns (3).

6- Edelweiss crowns

Edelweiss crowns are another esthetic option of preformed pediatric full coverage restorations. They were introduced in 2018 and are made of composite resin which is densely packed with sintered fillers of barium glass. They are supplied in various sizes with a size guide for proper crown selection. The crowns are biocompatible and easy to repair displaying normal wear behavior. Edelweiss crowns are bonded to teeth using composite resin after their fitting surface is roughened and treated with acid etch and bond (3).

E) Combination

1- Preveneered SSC

Pre-Veneered Stainless-Steel Crowns (PVSSCs) are SSCs with composite or thermoplastic resin facing. These crowns are luted to the tooth and combine the advantages of mechanical performance and durability of SSCs with the aesthetic appearance of composite (4). The aesthetic facing is either chemically or mechanically bonded to the crown (18). Initially, these crowns were introduced to restore anterior primary teeth. However, later, they were also developed to restore the primary molars (1, 19). Nusmile Primary Crowns, Kinder Krowns, Cheng Crowns, Flex Crowns, Dura Crowns, and Whiter Biter are several PVSSCs supplied in the dental market (20). The composite paste, iron, copper, silver, 2-hydroxyethyl methacrylate, chromium, nickel, zinc, manganese, silicon, molybdenum, cobalt, and carbon are examples of the materials used in these crowns (1). Sean Beattie et al. examined the fracture resistance of three pre-veneered stainless steel crown manufacturers in a study. They used EC crowns, Kinder Krowns, and NuSmile Primary Crowns in their research. Uniaxial load was applied to the crowns. There was no significant difference in fracture resistance between the crowns examined, and the forces required for fracture in each case exceeded the occlusal force of the control child in the 6 to 10 year age range (21). Their advantages include prolonged durability and pleasing appearance. Moreover, when the treatment area cannot be completely dry for composite placement, PVSSCs can provide an alternative pleasant restoration (22).

On the other hand, these crowns necessitate more aggressive tooth preparation compared to SSCs. They have some restrictions, such as premade resin shades that can appear fake (4). They are also wide mesio-distally making the crown placement challenging in individuals with crowding (19). Besides that, crimping the labial crown margin may weaken the facing and cause premature crown failure (18). Moreover, sterilization of the clinically tried in crowns introduces stresses on the resin facing (1). Therefore, steam sterilization is indicated to decrease these stress (18). Preformed stainless steel crowns can also be veneered with thermoformed high-density polyethylene. Besides their natural appearance, they display superior elasticity, and flexural strength together with good retention to the tooth substrate. Moreover, they do not often display chipping unlike other esthetic veneered crowns. Furthermore, they are difficult to disengage and able to be crimped both labially and lingually. Nevertheless, these crowns have a higher cost compared to SSCs or strip crowns. They are also difficult to repair in case of chipping.(3, 23).

2- Pedo pearls

These crowns are another type of pre-veneered crowns. They are composed of aluminum which is coated with epoxy paint giving them an attractive tooth-like color (19). They can be customized by cutting and crimping. Moreover, they can be covered with composite if necessary. However, their delicate construction and short lifetime are considered disadvantages (24).

2) Modified Prefabricated Pediatric Crowns

1-Open faced SSC

It is considered a modified prefabricated stainless-steel crown, which is commonly used to restore the primary incisors with fractured or broken crowns. As the preformed SSC crowns are the least attractive due to their dissatisfying silver color. They can be modified by the open-face stainless steel crown technique, taking advantage of strength and durability of preformed SSC with improved aesthetics and enhanced appearance of the teeth. Anterior and posterior teeth can be restored with this type of crown. They are contraindicated in patients with nickel allergy and uncooperative patients (1, 25).

Open-Faced Stainless-Steel Crowns were developed where a composite material is bonded on the labial surface of SSC. This can be performed by the dentist after cementation of the crown, by cutting away the facial surface of the crown using a 330 bur to create a window or labial fenestration on the cemented crown, followed by removal of the luting cement and exposing the underlying tooth structure leaving retentive undercuts. These grooves are filled with bonded composite resin. The crown should be cemented using GIC in cases where there is insufficient tooth structure to allow the composite to

bond directly over the cement after creating retentive undercuts (2).

To fabricate a successful open-face stainless steel crown, we should use phosphoric acid etching and dentin bonding agent to achieve a strong bonding resin to teeth. Irregularities may be formed on the remaining GIC to help for better mechanical retention. Open faced SSC are inexpensive esthetic restorations that allow an improvement over the unesthetic metallic appearance of stainless steel. But it has several limitations, as the procedure is time consuming and there is difficulty in controlling the bleeding which affects the resin and composite application which may lead to a short lifespan and poor color stability. Open face SSC has high liability of failure which occurs at resin-metal or resin-resin interface (26).

Drawbacks of preformed pediatric crowns:

1-Periodontal complications

The placement of preformed pediatric crowns may be associated with some gingival complications (27). Patients with poor oral hygiene may display increased plaque accumulation, gingival inflammation, and caries occurrence after crown placement (1). Consequently, when preformed crowns are decided as a treatment choice, patient and parental oral health education is mandatory to prevent such complications (1, 28). These problems may evolve as a result of inadequate crown contour or margins. Moreover, inadequate excess cement removal after crown placement may cause gingival inflammation due to irritation caused by the residual cement (1).

2- Metal sensitivity

Preformed metallic crowns contain nickel and chromium which may cause sensitivity in some patients (1, 29). However, metal allergy from SSC is rare because the recent preformed metallic crowns hold only about 5-12% nickel and 18-20% chromium (30). Nevertheless, metal ion release can occur due to corrosion which occurs as a consequence of the presence of rough margins and temperature rise during crown trimming (1). It was found that the release of nickel and chromium ions was at its maximum level during the first week after crown placement (29). Asude Yilmaz et al. reported a case of delayed hypersensitivity as a result of reaction to nickel after one week of SSC cementation (31). Besides this, a study reported an increase in nickel release with pH decrease. The ion release was at its highest level at a pH of 4.3 in artificial saliva (32). So, proper margin smoothening and polishing after crown trimming and oral hygiene instructions are important to avoid such drawbacks (1).

3-Biological aspect

Placement of any foreign material, including dental restorations, inside the patient's mouth might be accompanied with some sort of biological response. Metals including iron, nickel and chromium are proven to cause cytotoxic DNA damage in cultured cells (1). These metal ions can also result in dermatitis (29). Although some studies proved that there was considerable nickel and chromium ions release following the placement of SSC, the level of the released ions was below the toxic level. However, this ion level may cause metal sensitivity in some patients (1, 29). Likewise, composite based restoration may cause some biological hazards including estrogenicity, genotoxicity, and cytotoxicity as a result of residual monomer release from the restoration surface layer. A study conducted by Tugba Bezgin et al. showed that proper crown finishing and polishing is important to get rid of the surface free monomer-rich layer (33)

4- Esthetic limitations of metallic preformed crowns

Preformed metallic crowns display inferior aesthetics due to metal display. For this, SSCs can be replaced by composite based, polymeric or ceramic preformed or custom-made crowns which possess better aesthetics (1, 3).

3) Custom-Made Pediatric Crowns

Custom-made pediatric crowns are fabricated specifically for a certain patient and involve the same steps used to fabricate regular adult crowns. These techniques allow designing and fabricating crowns for cases where the prefabricated crowns are not suitable or do not fit the patient's tooth as they eliminate the need of adjusting the crowns to fit or over-preparing the tooth to allow the placement of prefabricated crowns. Partial coverage restorations are also possible only through custom-made methods (34). The main aim of custom-made crowns is to provide a more economical alternative to prefabricated esthetic zirconia or polymeric crowns. They also cause less trauma to the gingiva due to supragingival margins and elimination of the try-in crowns step (35). They are very useful where short crowns are required especially in the esthetic zone as prefabricated zirconia crowns cannot be trimmed (36).

A) Milled crowns (CAD/CAM – Computer Assisted Design/ Computer Assisted Manufacturing)

These types of crowns are obtained through an impression of the patient's prepared tooth. It could be obtained digitally through an intraoral scanner or a regular impression which can then be scanned with a bench scanner and converted into a virtual model. A computer software is used to design the crown and generate it as an STL file which is then supplied to a

milling machine to fabricate the crown from blocks or blanks of the desired material (subtractive technique). This technique allows for a customized single visit restoration with a minimally invasive preparation (37). Drawbacks include the milling time required and the lack of available morphologies of pediatric teeth in the designing software which might be time consuming as well to adjust the already available permanent teeth designs to be similar to the pediatric crowns (35, 38).

1- Ceramics

Zirconia is the ceramic of choice for pediatric crowns that are fabricated by milling to achieve esthetic anterior and posterior crowns with high strength. A clinical trial by Hanafi and Altinawi compared prefabricated zirconia crowns and milled ones. Both crowns preserved the marginal contacts and possessed high fracture resistance. However, they both had poor marginal adaptation (39). Zirconia crowns are more hygienic compared to polymeric crowns due to less plaque accumulation which improves gingival health. These crowns can be cemented using GIC or RMGIC or resin cements (40) 10-methacryloyloxydecyl dihydrogen phosphate (MDP) and silane which are included in some bonding agents can be used to improve the chemical bonding of zirconia to tooth structure (41).

2- Polymers

Polymeric CAD/CAM crowns are fabricated using PMMA (Polymethyl methacrylate) blocks such as Telio Cad (Ivoclar Vivadent). Compared to their manually fabricated counterparts, milled PMMA has higher fracture resistance, higher translucency, and better marginal adaptation. No residual monomers are produced during its fabrication making it more biocompatible to the cold-cured PMMA. Compared to zirconia crowns, however, they would have far lower fracture resistance values. The GIC and resin cements are used for their cementation (42).

3- Composite resins

Composite milled crowns are fabricated from highly crosslinked and pressed composites in the form of an interpenetrated network known as PICN (Polymer Infiltrated Ceramic Network). Some examples include Lava Ultimate (3M-ESPE), CERASMART 270 (GC) and VITA Enamic (VITA). They are characterized by durability and good marginal adaptation. Less abrasion occurs to opposing dentition due to lower hardness of composites compared to zirconia. They are biocompatible due to absence of residual monomer. Their fracture resistance lies between zirconia and polymeric milled materials. Self-adhesive resin cement is used for bonding without etching or using a bonding agent (43).

4- Polyetheretherketone (PEEK)

Polyetheretherketone was introduced to the field of dentistry as a high-performing, chemically inert biomaterial. This thermoplastic polymer is semi-crystalline with exceptional performance that can replace several prosthetic and restorative materials. It is produced when 4,4′-difluorobenzophenone and disodium hydroquinone salt react in a polar solvent such as diphenyl sulphone at 300 °C. The advantages of peek include its biocompatibility, low plaque affinity, and mechanical resemblance to enamel and dentin. It shows significant resistance to wear and chemicals. Its good thermal stability and dimensional stability up to 335.8 °C allow it to be used even after sterilization procedures. It offers radiolucent imaging, making it compatible with X-RAY, computerized tomography, and magnetic resonance imaging. This material has excellent polishing and esthetic qualities (44). Regarding full coverage, PEEK has also been seen as a promising substitute for ceramics.

B)3D printed crowns

Three dimensional (3D) printed crowns are fabricated using the same steps as milling except for the final step, where instead of milling the crowns from blocks of material, the materials are bound together in an additive manner layer-by-layer until the structure is built (additive technique). 3D printing techniques include FDM (Fused Deposition Modeling) or DLP (Direct Light Processing) or SLA (Stereolithography) (45). Milled crowns usually exhibit higher fracture resistance than 3D printed ones due to the compaction of the CAD/CAM blocks under high temperature and pressure which decreases flaws and voids between the particles (46). However, Small structures and surface details of occlusal anatomy are better depicted using 3D printing as it is difficult to achieve this with the large bur sizes in the milled restorations. In addition, there is less material waste due to being an additive technique where only the needed material is added contrary to CAD/CAM technique where the rest of the block will be discarded after milling (47).

1- Polymers

Methacrylate based temporary resin in liquid (used with DLP or SLA printers) or filament (used with FDM printers) form are used to form polymeric 3D printed crowns. Some examples include TC-80DP (Graphy) and GC Temp PRINT (GC). They can be cemented using GIC and resin cements. Despite their lower fracture resistance (1494 N) compared to the milled PMMA (1719 N), the fracture force exceeds the biting force of children in the primary molar region which ranges from 76 N to 106 N as demonstrated by Al-Halabi et al. (46). Kim et al, compared 3D printed resins to prefabricated zirconia crowns and there was

no significant difference in fracture resistance between these types of crowns and they all exceeded the average biting force of primary molars. Biaxial flexural strength was also tested which was inversely proportional to the thickness of the restoration (48). In a 12 months clinical trial, both printed and milled polymeric PMMA crowns showed proper marginal adaptation and retention (49).

2- Composite resins

Reinforced liquid resins such as C&B MFH (NextDent) contain some inorganic fillers in addition to cross-linked polymers. They are fabricated and cemented the same way as polymeric 3D printed crowns and provide higher fracture resistance than polymers due to the presence of fillers (41).

C) Shell crowns

Shell crowns are considered one of the easiest, cheapest techniques among the custom-made crown fabrication methods. They involve the use of materials that are readily available in the clinic which are used for fabrication of temporary indirect restorations for adults such as cold-cured PMMA or direct restorations such as composites. They are also repairable if chipping occurs by addition of composite or PMMA to the fractured part.

1- Polymers

Polymeric shell crowns can be fabricated by cold cured PMMA, Bis-acrylic resin or thermoplastic resin in the same manner by which temporary restorations for adults are fabricated. A silicone index is obtained for a sound tooth, then the material is injected in the index which is then placed over the prepared teeth until it sets. The index is removed, and some finishing and polishing can be done to the restoration. Although the bond strength would be quite adequate, the fracture resistance of the crowns will be compromised due to using non-reinforced materials with low stiffness in thin sections. The production of residual monomer will also pose a risk of irritation to the soft tissue as the material is allowed to set inside the patient's mouth. They are bonded using GIC (42).

2- Composite resins

In order to fabricate composite shell crowns, a flexible model is obtained after tooth preparation and is used to fabricate the crowns in a free hand manner over the model. A silicon index can be used to hold the crowns in place after their fabrication to transfer them for cementation in the patient's mouth without altering their positions. It is indicated for rehabilitation following early childhood caries and it provides a fast, easy, and cheap way of crown fabrication that could be done in a chair-side setting especially with uncooperative children. Despite these advantages, this technique is highly dependent on the clinician's skill to form the anatomy of the teeth and it will also require adjustments for the fabricated crowns to regain proper occlusion. These crowns can be cemented with resin cements (50).

CONCLUSION

A vast array of pediatric dental crowns is available to meet the demands of dentists in terms of durability, strength, and esthetics. The choice of the most suitable crown for the patient should be based on the patient cooperation, esthetic demands by the parents, extent of decay and the amount of available tooth structure as well as moisture control and ability of bonding the restoration to the tooth.

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