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ORIGINAL RESEARCH

Comparison of three-dimensional printed resin crowns and preformed stainless steel crowns for primary molar restorations: a randomized controlled trial

Ko Eun Lee[1,2,†], Hyun Seok Kang[1,†], Seo Young Shin[3], Taeyang Lee[2], Hyo-Seol Lee[3,4,*], Je Seon Song[1,2,*]

[1]Department of Pediatric Dentistry, Yonsei University Dental Hospital, 03722 Seoul, Republic of Korea
[2]Department of Pediatric Dentistry, College of Dentistry, Yonsei University, 03722 Seoul, Republic of Korea
[3]Department of Pediatric Dentistry, Kyung Hee University College of Dentistry, Kyung Hee University Medical Center, 03722 Seoul, Republic of Korea
[4]Department of Pediatric Dentistry, School of Dentistry, Kyung Hee University, 03722 Seoul, Republic of Korea

***Correspondence**
songjs@yuhs.ac
(Je Seon Song);
snowlee@khu.ac.kr
(Hyo-Seol Lee)

[†] These authors contributed equally.

Abstract

The importance of aesthetics in children has increased over time. Therefore, this multicenter randomized clinical trial aimed to analyze and compare three-dimensional (3D)-printed resin crowns (RCs) as a potential alternative to stainless-steel crowns (SSCs) for restoring primary molars with extensive carious lesions. According to the null hypothesis, no statistically significant difference was observed in restoration failure between RC and SSC groups. A total of 56 primary molars after pulp treatment at two dental hospitals were included. After pulp treatment, the teeth were randomly divided into two groups: SSCs (n = 28) and RCs (n = 28). At 1 week and 3, 6 and 12 months, the Quigley-Hein plaque index (QHI), gingival index (GI), occlusal wear, and survival rate were assessed by examination, radiography and alginate impressions. No significant difference in QHI was observed between the two groups. However, the GI at 12 months and occlusal wear in the RC group were significantly higher than those in the SSC group ($p < 0.05$). The survival rates were 100% in the SSC group and 82.1% in the RC group ($p = 0.047$). Cracks and discoloration were also observed in the RCs. Within the limitations of this study, 3D-printed RCs are aesthetically superior to SSCs and clinically easy to repair. However, if clinical effectiveness and safety are improved, RCs could potentially become a viable aesthetic alternative in the future.

Keywords

3D-printed resin crown; Stainless steel crown; Quigley-Hein plaque index; Gingival index; Occlusal wear; Survival rate; Primary molar

1. Introduction

Dental caries are common in children and adolescents and can lead to tooth decay. Restorative treatment is crucial to preserve the remaining tooth structure, restore chewing function, and maintain the integrity of arch length [1]. The American Academy of Pediatric Dentistry specifically recommends full-coverage restoration for children with extensive carious lesions or a high risk of caries, or for those who have received pulp therapy such as pulpotomy or pulpectomy [2–4].

Stainless-steel crowns (SSCs) are commonly used for full-coverage restorations owing to their ease of preparation and delivery, low cost, durability, and low incidence of secondary caries [5, 6]. However, SSCs may not be aesthetically pleasing to children and parents. To address this issue, new materials have been developed to improve aesthetics. One such material is zirconia crowns, which offer high strength and wear resistance, excellent biocompatibility, and corrosion resistance. Moreover, zirconia does not cause inflammatory reactions or allergies [7, 8]. However, zirconia crowns are more expensive and more difficult to modify using pliers or burrs compared to SSCs. In addition, they may not be suitable for children with bruxism because of the wear they inflict on opposing teeth [9].

Computer-aided design/computer-aided manufacturing (CAD/CAM) systems were introduced in dentistry in 1971, and the past 50 years have witnessed extensive advances from single-crown restorations to bridges, orthodontics, and implants. With advances in CAD/CAM technology and materials, fabricating prostheses using three-dimensional (3D) printers has become possible. Additionally, a 3D-printed resin capable of crown restoration of teeth has been developed [10, 11] and used for interim crown restoration [12, 13]. When comparing the conventional milling and 3D-printing method, the accuracy in the production of dental prostheses is comparable [14].

In pediatric dentistry, CAD/CAM and 3D printing technologies increase surgical precision, shorten dental procedure time, and increase the success rate of treatment. Additionally, 3D-printed surgical guides help safely extract deeply impacted supernumerary teeth [15]. Their usefulness extends to effective prosthetic treatment of school-age students with oligodontia [16] and for the testing of fracture resistance of zirconia crown restorations with additional post [17]. It applies to or-

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thodontic interventions, especially beneficial for patients who have difficulty producing alginate impressions. Moreover, the production of fluoride adhesive films for professional fluoride applications represents another aspect of diverse applications in dental research and practice [18].

Recently, a 3D-printed resin (Graphy, Seoul, Korea) for final prostheses was developed, which consists of urethane acrylate oligomer and methacrylate monomer and has a biaxial flexural strength and flexural strength of ≥350 MPa and ≥220 MPa, respectively [19]. Studies have compared 3D-printed resin crowns (RCs) and direct composite celluloid crowns for the final restoration of primary molars after pulpotomy, as well as CAD/CAM crowns using polymethyl methacrylate blocks with 3D-printed RCs [3]. In both studies, the group with RCs exhibited superior retention, marginal integrity, and gingival health compared to the control group. However, no clinical studies have compared 3D-printed RCs and SSCs.

This study aimed to compare SSCs and 3D-printed RCs for restoration of clinical primary molars after pulp treatment in terms of crown wear, fracture, gingival reaction, and dental plaque accumulation. The null hypothesis is that restoration failure is not significant different between RC and SSC groups.

2. Materials and methods

2.1 Resin crown fabrication

The crowns used in this study were 3D-printed RCs (TC-80DP, Graphy) and prefabricated SSCs (3M ESPE GA; St. Paul, Minn., USA). The characteristics of the 3D-printed RCs are listed in Table 1.

The RCs were manufactured directly with a 3D printer, following the subsequent process. First, a design file was required to fabricate the RCs. The frameworks for the crown design included SSCs of primary maxillary first and second molars and primary mandibular first and second molars, ranging in size from 3 to 7. An impression of the internal surface was obtained using polyvinyl siloxane impression material (Examix NDS, GC Corporation, Tokyo, Japan). The obtained impression was scanned using an intraoral scanner (Cerec Omnicam; Sirona, Bensheim, Germany), and the crown was designed using a dental CAD software program (version 3.0, Exocad Gmbh, Darmstadt, Germany) (Fig. 1a). Additionally, all surfaces of the crown were uniformly designed with a thickness of 0.641 mm (Fig. 1b). An inadequate thickness can lead to distortion during printing and an increased risk of fracturing, whereas excessive thickness may require a substantial amount of tooth removal, resulting in an overly bulky contour. Therefore, the crown was produced with a thickness of 0.6–0.65 mm.

The design file was created in standard tessellation language (STL) format and converted to a format compatible with a 3D printer (Sprintray Pro95, Graphy Inc., Seoul, Korea) suitable for the resin product. The layer thickness of the resin crown printed using the digital light processing (DLP) method was set to 50 μm, and crowns for maxilla/mandibular primary first and second molars ranging from sizes 3 to 7 were printed. The printed crowns were cleaned using a 3D-printed object washer (Twin Tornado, Medifive, Seoul, Korea) and a 3D-printing cleaner (Twin 3D Cleaner, Medifive) for 20 min for primary and secondary cleaning. The supports attached to the crown were removed, along with the excess cleaner on the crown surface using air. The crown was then cured for 15 min on both sides using a postcuring device (CureM U102H; Graphy Inc., Seoul, Korea).

The areas where the supports were attached were polished using gray rubber silicone polishers, and the debris was removed using an ultrasonic washing machine (Twin Tornado, Medifive, Seoul, Korea) for 5 min. The fabricated crowns were sealed in pairs according to their size and crown type and then subjected to ethylene oxide gas sterilization (Fig. 1c).

2.2 Study design

This multicenter controlled trial included two departments of pediatric dentistry at Yonsei University and Kyung Hee University of Dental College. Children diagnosed with extensive dental caries requiring crown restoration after pulpal treatment were eligible for this study.

The inclusion criteria were as follows: age of 4–7 years; both children and parents/guardians provided informed consent; the tooth to be treated will remain in place for >2 years before exfoliation; with tooth needing pulp treatment; and stable occlusion. Meanwhile, the exclusion criteria were as follows: disabilities and systemic diseases; poor behavior such as Frankl behavior classification scale of 3 or 4; temporomandibular joint disorder; and detrimental oral habits such as bruxism.

Research nurses, who did not participate in the study, randomly divided the patients into two groups: group 1 (3D-printed RCs) and group 2 (preformed SSCs (3M, St. Paul, MN, USA)).

Dental treatments including pulp treatment with crown restorations were performed. Thereafter, periapical view, intraoral photography, quantitative light-induced fluorescence (QLF) (Q-ray view C; All-in-one Bio, Seoul, Korea), impression taking, and clinical assessment were performed at regular examinations after dental treatment at 1-week and, 3, 6 and 12 months (Fig. 2).

2.3 Clinical procedures of crown restoration

All children were treated under local anesthesia. Extensive dental caries requiring pulpal treatment was the indication; therefore, pulpotomy or pulpectomy was performed. The occlusal reduction for SSCs typically ranges from 1.0 to 1.5 mm, although the values may vary depending on the occlusal relationship. In the proximal areas, a thin, long diamond bur was used to create a feather-edge margin to ensure that no ledges were present. All the line angles were treated with rounded contours. In the SSC group, a crown of appropriate size was selected based on the mesiodistal width and fixed to the tooth with glass ionomer cement (GC Fuji II; GC, Tokyo, Japan). Owing to the crown thickness, the RC groups required greater tooth preparation than the SSC groups. The occlusal reduction for RC ranges from approximately 1.5–2.0 mm. However, the range can vary depending on the occlusal relationship, and reduction of opposing teeth may be necessary. The RC should ensure a passive fit, allowing the crown to be seated adequately with sufficient preparation to

TABLE 1. Manufacturing detail and material composition of 3D-printed resin.

Manufacturer	Product	Shade	Composition	Batch number
Graphy	TC-80DP	B1	Methacrylate oligomer based on polyurethane resin, phosphine oxides, and pigment	1-B1220K11-003

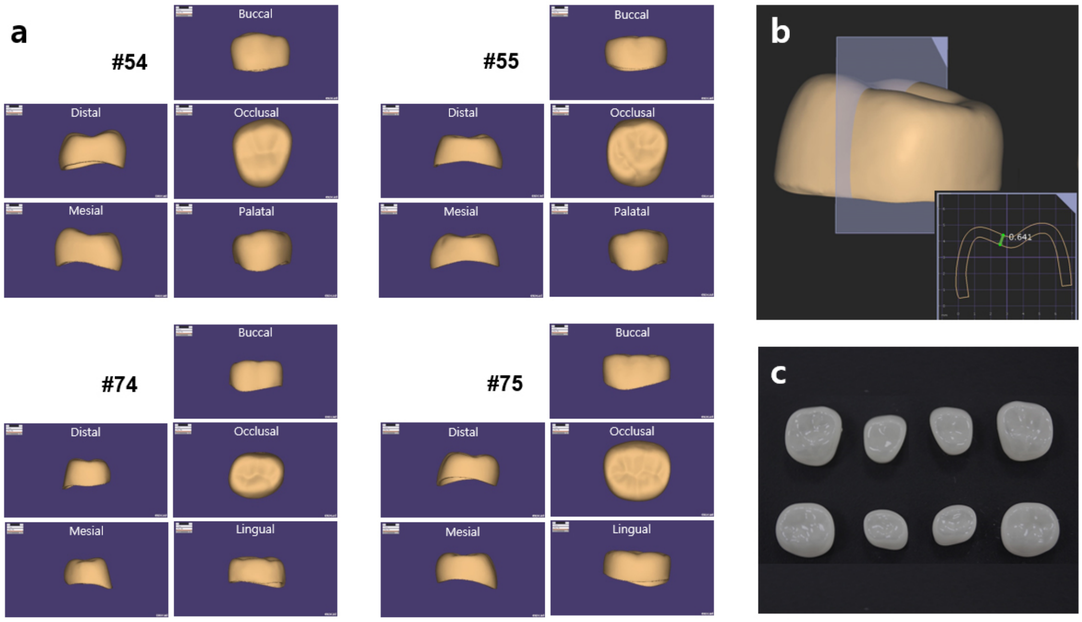

FIGURE 1. The design and the final restoration of 3D-printed resin crowns. (a) The design of maxillary right first, maxillary right second, mandibular left first, and mandibular left second molars. The opposite side of the dentition is designed with mirror symmetry. (b) The resin crown is designed with a regular thickness of 0.641 mm. (c) The final restoration of 3D-printed resin, of size 5, after polishing and before sterilization.

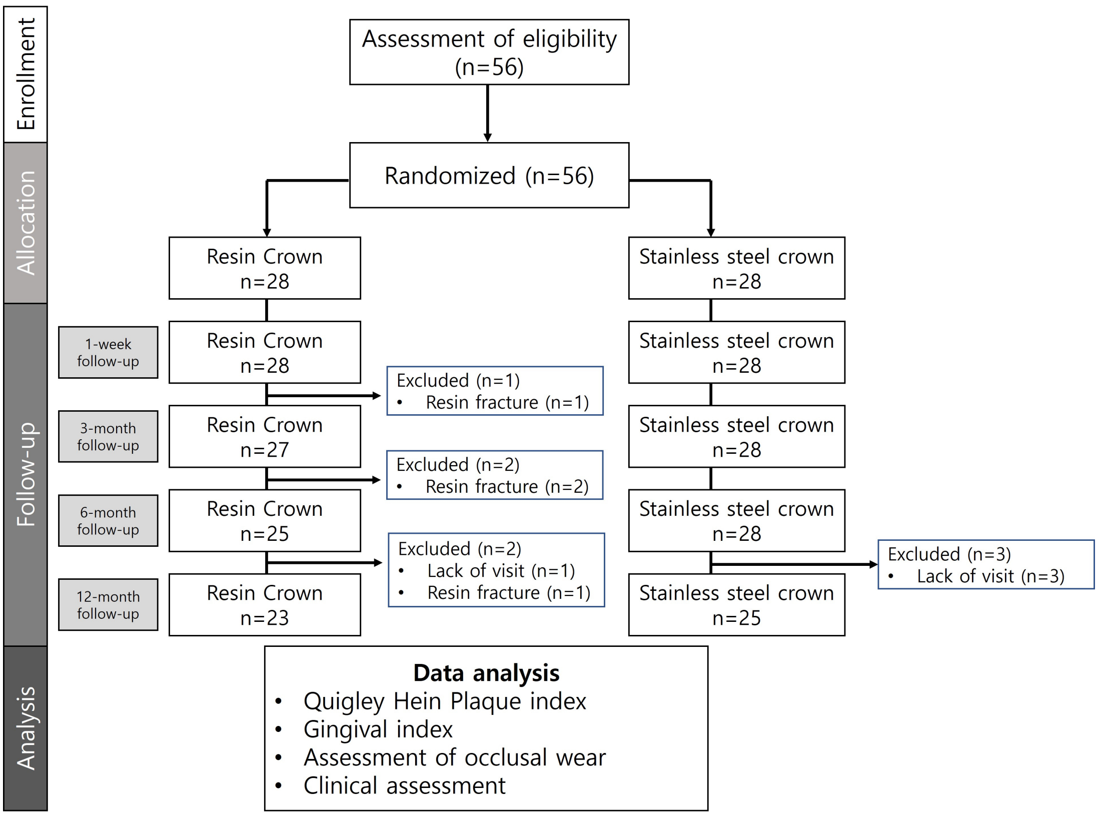

FIGURE 2. Consort flow diagram.

reach the desired position according to the dentist's preference. The interproximal walls were made parallel or tapered for passive attachment of the crown, and a 1mm subgingival margin with a feather-edge design was recommended. Before cementation, the occlusion was evaluated using a try-in-resin crown of the same size. If the occlusion was excessively high, additional occlusal reduction and margin preparation were performed; at times, the occlusal contact points on the opposing teeth were also reduced. The final occlusion was verified using a shimstock in both posterior regions. The teeth were etched with acid gel for 30 s, washed, and dried. Subsequently, a self-etch bonding agent was applied, and the sample was cured for 30 s. During this procedure, the RCs were filled with resin cement (Rely X Ultimate Clicker, 3M) and seated on the tooth. After 2 s of curing, excess cement was removed and the crown was cured for another 30 s. During regular follow-up, if the RC may be partially fractured with a small fracture size, the crown is easily and rapidly repaired with etchant, self-etch bonding, and composite resin (Tetric Ceram; Ivoclar/Vivadent: Schaan, Lichtenstein).

2.4 Assessment of plaque accumulation and gingival inflammation

The pattern and amount of plaque deposition on the attached crown were evaluated using the Quigley-Hein plaque index (QHI) [20]. The assessments were performed by a well-trained specialized dentist at each institution. Moreover, the examiner evaluated the facial and lingual surfaces of the crown and the QHI was as follows: "0", no plaque; "1", isolated flecks of plaque at the gingival margin; "2", a continuous band of plaque up to 1 mm at the gingival margin; "3", plaque greater than 1 mm in width and covering up to one-third of the tooth surface; "4", plaque covering approximately one-third to two-thirds of the tooth surface; and "5", plaque covering two-thirds or more of the crown of the tooth.

The gingival index (GI) [21] was used to evaluate gingival inflammation after each crown. The GI is a valuable tool for evaluating the condition and qualitative changes of the gingiva. In this study involving healthy children, only gingival color and edema were assessed and scores were assigned. However, bleeding on probing was not assessed. The examinations were performed by a specialized dentist at each institution. The index rated from "0", normal gingiva; "1", mild inflammation; "2", moderate inflammation; and "3", severe inflammation.

2.5 Quantitative analysis of wear

Furthermore, 1-week and, 3, 6 and 12 months after tooth restoration with a crown, the patient returned for an impression-taking procedure using alginate. Fast-set alginate was used to minimize patient discomfort during the process. A study cast was created based on these impressions. After trimming the produced study cast and carefully removing any bubbles, a three-axis blue light-emitting diode scanner (T310, Medit, Seoul, Korea) was used to obtain the STL format file of the cast. Subsequently, the STL file from the 1-week check-up was used as a reference, and those from the 3, 6 and 12-month check-ups were compared using the 3D inspection software (Geomagic Control X, 3D Systems, USA).

By comparing the STL files of the 1-week model after restoration with those of the check-up models at 3, 6 and 12 months, measuring the amount of wear over time was possible. When comparing the models over time, the surrounding tissues and teeth may have changed; therefore, areas other than the target crown were excluded before comparison. Additionally, if the crown had a fracture or a piece had fallen off, it was excluded from the comparison.

The results of the wear analysis are presented as root mean square (RMS) values. The maximum and minimum critical values were established at 50 μm and -50 μm, respectively. The RMS is expressed as follows [22, 23]:

$$MS = \frac{1}{\sqrt{n}} \bullet \sqrt{\sum_{i=1}^{n} (x_{1,i} - x_{2,i})^2} \quad (1)$$

In the formula, "$x_{1,i}$" represents the scan data of the model obtained 1 week after the restoration, which serves as the reference data, and "$x_{2,i}$" represents the scan data of the model obtained $\geq$3 months after the restoration, which serves as the comparison data.

2.6 Survival rate and clinical assessment of resin crown

The survival rate was defined as the rate of crown presence 12 months after crown attachment. Clinical success standards are listed in Table 2. Furthermore, QLF images are useful for detecting early caries and crack lines in teeth and restorations [24]. These images of the buccal, lingual, and occlusal surfaces were captured by a specialist using a Qraypen C (AIOBIO, Seoul, Republic of Korea). "Clinical success" refers to a case where a defect is present, although follow-up observation is possible or when it can be easily addressed in an outpatient setting. In other words, if the re-restoration with another crown is not necessary (which is determined by a specialized pediatric dentist), the case is considered as "clinical success".

2.7 Statistical analysis

To determine the sample size, G*power version 3.1.9.4 (Heinrich-Heine Universität, Düsseldorf, Germany) was used, based on previous papers [25] with an expected effect size of 0.8, an alpha of 0.05, and a power of 0.80. Moreover, 21 teeth were required for each group, and considering a dropout rate of 25%, a total of 56 teeth were analyzed, 28 teeth in each group.

Shapiro-Wilk test was performed to determine the normality of the distribution of occlusal wear. As a result, both RC and SSC groups were normally distributed. Mann-Whitney U and independent *t*-tests were performed to compare the differences between the SSC and RC groups. Survival rates were described using Kaplan-Meier analysis and log-rank tests. The data were analyzed using IBM SPSS Statistics 20 (IBM Corp. NY, Armonk, USA). The significance level was set at $p < 0.05$.

TABLE 2. Criteria for success and failure of 3D-printed resin crowns.

Score	Status of 3D-printed resin crown	Success/Failure	Subsequent treatment
0	None	Success	None
1	Crack line	Clinical success	Follow-up
2	Partial fracture on one surface of the crown	Clinical success	Resin adding
3	Partial fracture on two surfaces of the crown	Failure	Change to stainless steel crown
4	Partial fracture on three faces of crown or fallen out	Failure	Change to stainless steel crown

3. Results

In total, 56 teeth were included in the study: RCs (n = 28) and SSCs (n = 28). Due to patient noncompliance with hospital visits, one patient from the RC group and three from the SSC group were excluded from the study. Additionally, four teeth in the RC group experienced procedural failures. After 12 months, RCs (n = 23) and SSCs (n = 25) were analyzed.

3.1 Assessment of plaque accumulation and gingival inflammation

No statistically significant differences were observed in the plaque index based on the type of crown or the passage of time. However, except at the follow-up after 1 week, the plaque index was worse in the RC group compared to the SSC group. The mean of QHI of SSCs at 1 week and, 3, 6 and 12 months were 0.93 (±1.07), 0.75 (±0.87), 0.42 (±0.64) and 0.67 (±0.94), respectively. In addition, the mean of QHI of RCs at 1 week, 3, 6 and 12 months were 0.79 (±0.67), 0.96 (±0.73), 0.75 (±0.74) and 1.0 (±0.76), respectively (Fig. 3a).

No significant difference in the GI at 1 week and, 3, 6 and 12 months between the types of crowns was observed, but the GI of the RC group significantly increased at 12 months compared to that of the SSC group. The mean of GI of SSCs 1 week and, 3, 6 and 12 months were 0.64 (±0.48), 0.50 (±0.50), 0.17 (±0.37) and 0.10 (±0.30), respectively. In addition, the mean of GI of RCs at 1 week, 3, 6 and 12 months were 0.36 (±0.48), 0.61 (±0.72), 0.39 (±0.62) and 1.0 (±0.30), respectively (Fig. 3b).

3.2 Assessment of occlusal wear

The amount of occlusal wear over time was calculated using the difference in the RMS values. The mean of the SSC group ranged from 0.021 (±0.01) to 0.025 (±0.01), and no significant difference in wear was observed over time. However, in the RC group, the wear of the occlusal surface increased over 3, 6 and 12 months, with mean values of 0.064 (±0.02), 0.079 (±0.02), and 0.125 (±0.05), respectively. No significant difference in the wear of RCs was observed between 3 and 6 months ($p > 0.05$), whereas a significant difference in the wear of RCs was identified between 6 months and 1 year ($p < 0.05$).

Occlusal wear in the RC group was significantly higher than that in the SSC group at 3, 6 and 12 months ($p < 0.05$) (Fig. 4).

3.3 Survival rate and clinical assessment of resin crown

No failures were observed in the SSC group after 12 months of dental treatment. In contrast in the RC group, one failure occurred after 3 months (Survival rate = 96.2%), and two cases were changed to SSCs after 6 months (Survival rate = 88.9%) because of fracture of three surfaces. Finally, a total of four crowns failed at 12 months, resulting in a survival rate of 82.1% for RCs. The success rate of RCs was significantly lower than that of SSCs ($p = 0.047$) (Fig. 5).

Wear was observed at a high rate, yet the mesiodistal width remained well maintained. Crack lines were observed at the 3-month follow-up. When fractures were limited to one surface, they could be readily repaired by the addition of a resin. However, if fractures were detected on more than two surfaces of the RC or if the patient visited the clinic with a fallen crown, it was classified as a failure and subsequently replaced with SSCs. Discoloration was frequently detected in the RCs (Fig. 6).

4. Discussion

This study aimed to investigate the use of 3D-printed RCs as a potential alternative to SSCs, which is the standard clinical treatment for restoring pulp-treated primary molars. An SSC, which exhibited the lowest failure rate in the restoration of primary molars, was selected as the control group [6]. The study followed up the restorations for 1 year. No issues were detected in the SSC group, whereas wear, fractures, and discoloration were observed in the RC group.

The oral cavity is a complex environment that harbors various types of microorganisms leading to the formation of a biofilm [26]. Particularly, areas such as teeth and prosthetics in the oral cavity are susceptible to plaque accumulation, which can cause infectious diseases such as gingivitis [27, 28]. The RC group demonstrated worse results in terms of gingival and plaque indices than the SSC group, although the difference was not significant. Rough surfaces tend to promote biofilm formation [29, 30]. Generally, the surfaces of RCs are rougher than those of SSCs and milled crowns [31]. In addition, polishing in resin can affect bacterial adherence [32] and owing to the lack of an established RC polishing method, the surface roughness of the crown is higher than that of the SSC surface. Therefore, the index score may be poor.

Based on the results of this study, RCs exhibited a lower wear resistance than SSCs. Compared to the SSCs, which did not display any difference in the degree of wear during the follow-up period, the RCs demonstrated an increased wear

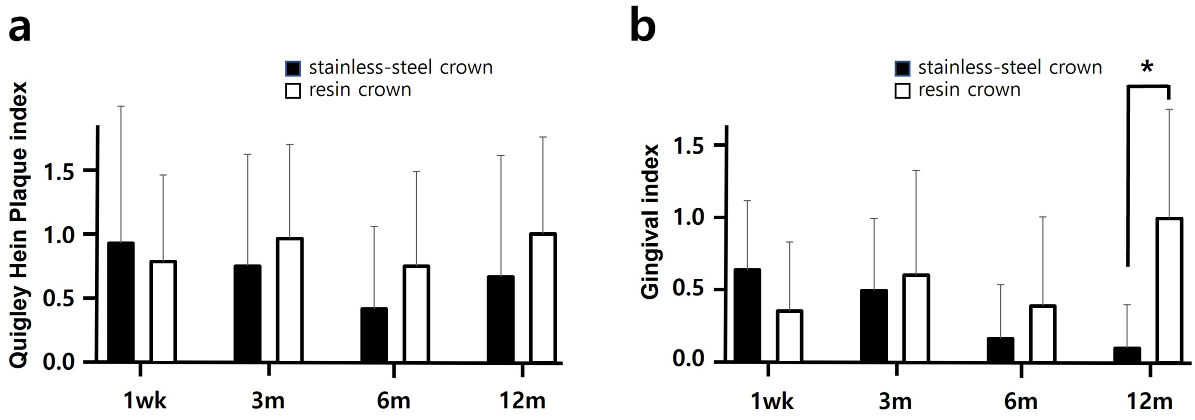

FIGURE 3. Quigley-Hein plaque index and gingival index. (a) Quigley-Hein plaque index. (b) The gingival index demonstrated significant differences at 12 months. "*" represent significant differences between the materials ($p < 0.05$).

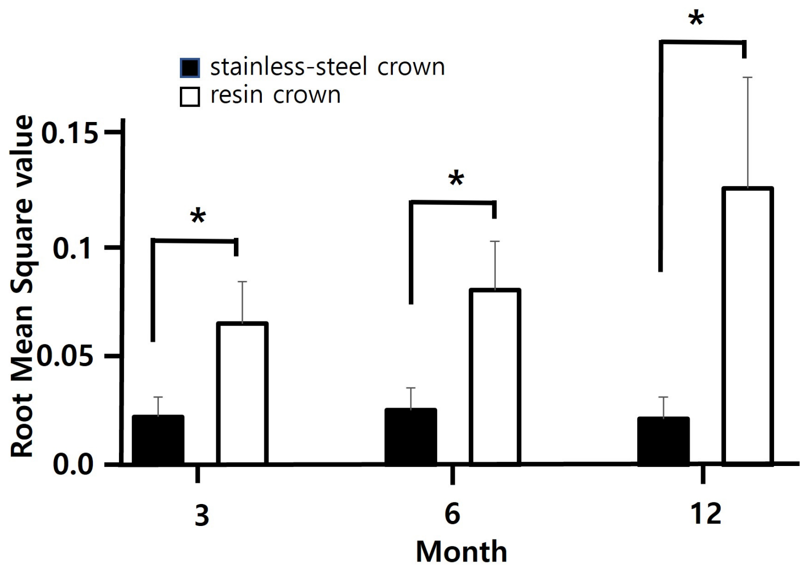

FIGURE 4. Assessment of occlusal wear. The occlusal wear of RC groups statistically significantly increased compared to SSC groups in 3, 6 and 12 months. "*" represent significant differences between the materials ($p < 0.05$).

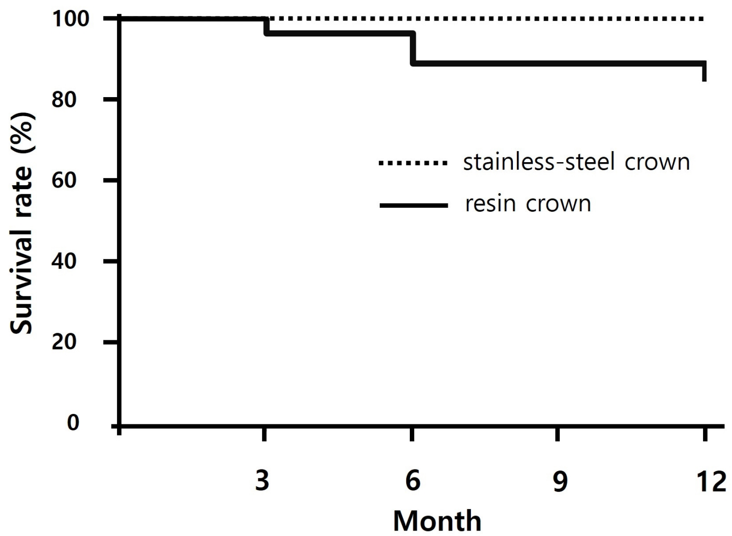

FIGURE 5. Cumulative survival rate depending on the type of crown relative to time.

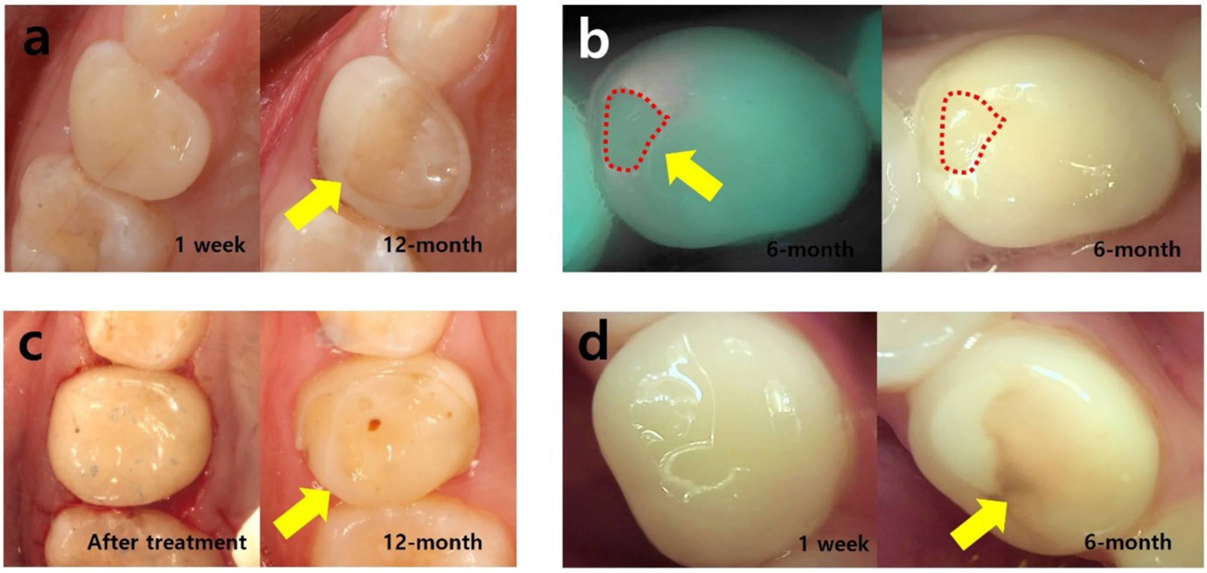

FIGURE 6. Clinical assessment of resin crown. (a) Occlusal wear is observed after 12 months compared to 1-week follow-up. (b) Partial fracture on the occlusal surface. (c) Severe crown fracture involving three surfaces (d) Discoloration appeared at the 6-month follow-up.

pattern over time. In a wear study with a chewing simulation, 3D-printed resin had similar wear as that of milled and conventional self-cured resins [33]. However, considering the material properties of the polymer and the ductility of the metal, RCs naturally displayed more wear than SSCs.

Of the 28 RCs, crowns falling off of more than two surfaces with fractures were observed in four cases, and one case was lost to follow-up. The survival rate was 82.1%, which was significantly lower than the 100% survival rate of the SSC group. During tooth preparation, RCs had a thicker crown than SSCs; however, additional tooth preparation was performed without adjusting the inner surface of the crown despite the inner adjustability of the RC to maintain this thickness. Similarly, in the case of the occlusal surface, considering the greater occlusal crown thickness and the reduced flexibility of the resin compared to stainless steel, performing more preparations for the occlusal surface was necessary, which could result in a greater amount of preparation for RC than that for SSC. Despite minimal interference with the RC during restoration, crack lines and fractures were observed. Crack lines were frequently observed during check-ups in the RC group, along with horizontal crack lines. The reason for the aforementioned crack lines seems to be that the layer was stacked and fabricated by the digital light processing DLP method, which resulted in a low cure depth. The difference in surface roughness may have had influenced crack initiation. According to studies on children's bite force, the maximum bite force of children aged between 3 and 5.5 years has been reported to be 186.2 N and 235 N, respectively, and the maximum bite force of children aged between 6 and 11 years has been reported to be 330.5 N and 374.4 N, respectively [34, 35]. In the fracture resistance test, 3D-printed RCs with 0.7 mm thickness were tested; fractures appeared at a force higher than 900 N [19], which is significantly higher than the children's biting force. Although the fracture study was conducted without aging processes, such as temperature, humidity, and chewing simulation, the fact that the crown fractured and fell out in less than a year indicates the need to consider the durability of the RCs.

Upon inspection of the RCs, discoloration was noticeable, even though less than a year had passed since their placement. As 3D printing is an additive manufacturing method, a microstructure is inevitably created for each layer [36, 37]. In addition, 3D-printed resins have a less compact structure owing to their low polymerization compared to other materials, which results in low color stability [38, 39]. Moreover, RCs exhibit a relatively low degree of polymerization, even with post-curing. The presence of residual monomers and compromised interlayer integrity due to the slow polymerization rate heightens the likelihood of discoloration [40, 41].

Crown restoration should firmly protect the deciduous tooth until the permanent tooth emerges successfully. However, the occurrence of cracks and fractures within less than a year may indicate failure of the crown to fulfill its role, suggesting the need for improvements in the physical characteristics. Research is required to determine the optimal crown thickness and shape, considering the manufacturing process of the DLP method and the inherent properties of the resin to enhance durability. Furthermore, clear guidelines for post-fabrication polishing and glazing processes are yet to be established. In terms of dental plaque deposition and extrinsic discoloration, a need for guidelines exists for the optimal finishing stages of fabrication.

Despite the occasional cracking or discoloration of RCs, parents' aesthetic satisfaction with RCs was very high at 1-year check-ups, and most of them opted for RCs when the other teeth needed to be fully restored.

The initial costs of 3D printing, cleaning, and post-curing equipment, and resin for 3D printing may be substantial. However, once the manufacturing process is established with clear design files in the STL format, the crown can be mass-fabricated in a laboratory at any time. In the long term, RCs are anticipated to be more cost-effective than certain types of prefabricated crowns.

One limitation of this study is that none of the children had the same bite force. Furthermore, children with parafunctional habits were screened; however, a possibility exists that children with habits that were not known to the parents but only to the patients themselves may not have been excluded from the study, which could have influenced the results. Additionally, the printing process remains consistent in the production of RCs; however, due to the removal of the abutment and the manual polishing process, RCs may exhibit less physical uniformity compared to SSCs. The surface roughness of the crown can affect crown fracture resistance [42]. Furthermore, RCs that have not undergone optimized surface polishing may exhibit lower fracture resistance owing to their rougher surfaces than those of SSCs. In the case of RC, the margin type was feather-edged, and the use of prefabricated crowns without impression-taking inherently led to potential marginal gaps. However, efforts were made to fill these gaps using resin cement, and apart from the GI at the 12-month follow-up, no significant differences were observed in the gingival and plaque indices. However, acknowledging the clear limitations of this approach is crucial. Considering the potential for the wash-out of resin cement, further research is necessary to explore the optimal margin type for RC restorations. A plaster model was manufactured using alginate impressions to compare the wear degree. However, the generated air bubbles during the impression-taking process cause errors when comparing the wear degree. Creating study casts without bubbles was possible after several rounds of impression-taking. However, obtaining multiple impressions proved challenging because of the discomfort experienced by the children.

5. Conclusions

Within the limitations of this study, 3D-printed RCs are aesthetically superior to SSCs and clinically easy to repair. However, the clinical safety and effectiveness of RCs have not been conclusively established. If the clinical usage of RCs improves, they could potentially become viable aesthetic alternatives.

ABBREVIATIONS

SSC, stainless steel crown; RC, resin crown; QHI, Quigley-Hein plaque index; GI, Gingival index; CAD/CAM, computer-aided design/computer-aided manufacturing; 3D, 3-dimensional; QLF, quantitative light-induced fluorescence; RMS, root mean square; STL, standard tessellation language.

AVAILABILITY OF DATA AND MATERIALS

The data are contained within this article.

AUTHOR CONTRIBUTIONS

HSL and JSS—designed the research study. KEL, HSK, TL and SYS—performed the experiments. KEL, HSK, SYS, HSL and JSS—provided assistance and advice for this study. KEL and HSK—analyzed the data; wrote the manuscript. All authors contributed to the editorial changes in the manuscript. All the authors have read and approved the final version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was conducted following the Declaration of Helsinki. The study protocol was reviewed and approved by the Institutional Review Boards of Yonsei University Dental Hospital, Seoul, Korea (IRB no. 2-2021-0010) and Kyung Hee University Dental Hospital, Seoul, Korea (KH-DT22002). The eligibility for research was assessed, and informed consent was obtained from both the parents/guardians and patients.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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