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ORIGINAL RESEARCH

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Retrospective evaluation of occlusal adaptation of stainless steel crowns applied under deep sedation

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Abstract

Background: The objective of this study was to retrospectively assess the occlusal adaptation, marginal adaptation, and other clinical pathologies of stainless steel crowns (SSCs) performed under deep sedation. **Methods**: Patients who received SSCs under deep sedation between January 2022 and January 2023 and underwent clinical follow-ups, along with photographic/radiographic evaluations if available, at the 1st week, 1st, 3rd and 6th months, were planned to be included in the study. Furthermore, patients were included in the study if they were evaluated for marginal adaptation of SSC, occlusal adaptation of SSC, fracture or decementation of SSC, abscess/fistula formation, and sensitivity to palpation or percussion during clinical follow-ups. These findings were recorded retrospectively. Accordingly, 24 patients who met the specified criteria were included in this study. The data was analysed with Wilcoxon Signed-Rank test (significance level was set at 0.05). **Results**: In the first week, successful occlusal adaptation (SOC) was observed in 83.33% (n = 20) of the cases. Also, no other clinical failures or marginal inadaptibility were found in any patient. In the marginal adaptation and clinical success, there was no statistical difference between the examination periods in terms of the number of successful cases (p = 1.000), while the successful cases in the occlusal adaptation evaluation in the first week was statistically lower than those who were successful in further examination periods (p = 0.046). **Conclusions**: Within its limitations, this study demonstrated that the occlusal adaptation of SSCs placed under deep sedation was acceptable even in the immediate postoperative period. The results are thought to be influenced by the adaptive masticatory system of children. Therefore, it was suggested that acceptable occlusal harmony could be achieved by referencing the adjacent and opposing teeth during SSC placement. Nonetheless, further clinical studies are required to validate these findings.

Keywords

Deep sedation; Marginal adaptation; Occlusal adaptation; Stainless steel crown

1. Introduction

Due to mental/physical disabilities or additional systemic diseases, it may not always be feasible to complete essential treatment in the clinical setting for children with dental anxiety who exhibit inadequate cooperation with the dentist. In such cases, pediatric dentists employ non-pharmacological or pharmacological behavior management techniques [1–4]. The American Academy of Pediatric Dentistry (AAPD) has reported that pharmacological options such as sedation and general anesthesia, considered advanced behavior management techniques, can be effective when basic techniques like tell-show-do, ask-tell-ask, voice control, non-verbal communication, positive reinforcement, desensitization, and descriptive praise, are insufficient [1, 3, 5].

Dental caries is a chronic disease that can be seen quite commonly in childhood. Restorative treatment options after removal of carious tissue during dental treatment include restorations made with various dental materials (such as compomer, glass ionomer and composite) and prefabricated pediatric crowns [6–9]. AAPD recommends the application of crown restorations especially in children in high caries risk group or in primary molars with extensive caries lesions [10]. Moreover, dental caries prevalence and severity are often higher in non-cooperative children. In such cases, restoring teeth with a crown may be more appropriate than using conventional restorative materials, which could lead to questionable prognosis [11].

Primary teeth with widespread crown damage have been successfully treated with stainless steel crowns (SSCs) for many years. Although the SSCs still constitute the golden standard and have been used successfully for over 70 years, they often fail to meet the demands of patients and parents in terms of esthetics. Prefabricated zirconia crowns are the

relatively new materials introduced to accomplish an esthetic outcome which are available from different manufacturers. The most important advantage of zirconia crowns is that gingival and plaque indices are lower among these crowns than other crown types [8, 11]. However, these crowns have certain disadvantages such as (i) They are very technique sensitive, (ii) They require excessive tooth preparation to provide a passive fit, and (iii) They are not cost-effective [12]. Therefore, SSCs, although esthetically disadvantageous, are still widely preferred due to their advantages such as durability, long-term clinical life, ease of use and being relatively inexpensive [9].

Furthermore, there is limited literature on the application of SSCs under general anesthesia in dentistry [11, 13–15]. Schüler *et al*. [11] reported successful results of SSC application under general anesthesia, whereas Patel *et al*. [15] found that patients who received SSC placement during initial treatment under general anesthesia may experience a reduced need for retreatment in the future. However, there are several clinical challenges associated with performing SSCs when the patient is under general anesthesia or sedation. In a clinical setting, occlusal adjustment and height control can be readily performed during treatment. However, in placements carried out under sedation or general anesthesia, the use of a mouth opener can hinder achieving the necessary level of occlusal adaptation and height control required for SSC placement. Patients with impaired or insufficient occlusal adaptation after treatment may be at risk of temporomandibular joint damage in the future [9–11, 13–15]. However, it is also suggested that discrepancies in crown height may resolve over time due to the adaptive nature of the joint structure in children, even in techniques like the Hall technique where no tooth preparation is performed [16–18]. To the best of our knowledge, there is no study in the literature evaluating the occlusal adaptation of SSCs applied under sedation. Therefore, based on this preliminary information, the aim of this study was to evaluate the occlusal adaptation of SSCs performed under deep sedation.

2. Materials and methods

2.1 Sample calculation

This retrospective cohort research aimed to evaluate all cases from the previous year (January 2022–January 2023) where stainless-steel crowns were utilized in treatments at the pediatric sedation unit of the Ankara University, Faculty of Dentistry, Department of Pediatric Dentistry. Since all patients meeting the inclusion criteria were included in the study, a separate sample analysis was not necessary. The inclusion criteria for the cases are outlined below.

2.2 Study design

The presented study has followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for in-vitro studies as discussed in the 2007 concept note by Von Elm *et al*. [19].

2.3 Inclusion criteria

• Pediatric patients receiving dental treatment under deep sedation at the pediatric dentistry clinic in the previous year.

• Patients with unilateral SSCs applied for indications such as multisurface dental caries or endodontic treatment (*e.g.*, pulpotomy or pulpectomy).

• Patients without acquired or congenital tooth agenesis on the opposite and/or contralateral side of the dental arch where SSCs were applied.

• Patients without any dental or skeletal orthodontic anomalies.

• Patients with photographic or radiographic records available for the 1st week, 1st, 3rd and 6th month follow-ups.

• Patients with SSCs that were assessed for marginal adaptation and occlusal adaptation during the aforementioned follow-up periods.

2.4 Exclusion criteria

- Patients with SSCs applied under routine clinical procedures other than deep sedation.

- Patients without clinical, photographic or radiographic follow-up records at the above-mentioned intervals.

- Patients with congenital tooth agenesis on the opposite and/or contralateral side.

- Patients with dental or skeletal orthodontic anomalies.

- Patients with bilateral SSCs.

2.5 Clinical procedure

A total of 24 SSC restorations were included in the study, with 14 placed in primary second molars and 10 in primary first molars. These restorations were performed on 24 patients with an age range of 4 to 8 years old, with a mean age of 6.44 years, all of whom met the inclusion criteria. The clinical protocol for the placement of SSCs were the following steps: (1) Pre-evaluation of the patient's teeth for tooth shape, points of contact with antagonist and neighboring teeth, and occlusion sites. (2) Caries removal and endodontic treatment were performed as needed. Among the 24 teeth, 10 underwent pulpotomy, and 1 had pulpectomy, while the remaining 13 had caries. During the endodontic treatments, local anesthesia was applied according to the tooth type. (3) For non-pulpally involved caries, cavities were restored with a glass hybrid restorative system (Equia Forte® HT) after caries removal. If endodontic treatment was performed, tooth preparation was carried out after restoring the pulp chamber with Equia Forte® HT. (4) A prefabricated SSC (3M™ ESPE™ Stainless Steel Primary Molar Crowns, Dental Products, Conway Avenue, USA) was selected to cover all occlusal cusps and provide a "spring-back" sense for contact areas. (5) The tooth crown was reduced to 1.5 mm from the occlusal surface and 1 mm from the mesial and distal approximal surfaces during preparation. All sharp margins were removed and checked. (6) Crown adjustment was done with reference to the occlusal surface, dimensions of adjacent and opposing teeth, and the treated tooth, considering the occlusal curve of the dental arch. (7) Crown margins were contoured circumferentially to follow the natural borders of the marginal gingiva. Marginal adaptation was examined by

moving a dental probe circumferentially along the marginal edges, with poorly adapted regions adjusted using a plier. (8) The tooth was isolated from saliva contamination with a cotton roll, and both the tooth and SSC were dried. (9) Glass ionomer luting cement (Meron, Voco GmbH, Germany) was prepared according to the manufacturer's instructions and applied to the internal surfaces of the crown. (10) The crown was placed on the prepared tooth structure using finger pressure. Excess luting cement was removed with a probe or dental floss. (11) Patients whose restoration was completed received oral hygiene training upon discharge. (12) A soft diet was recommended, discouraging consumption of sticky or hard foods for a few days post-operatively to minimize stress on the SSC and the underlying tooth. (13) Radiographic control was left out the inclusion criteria as the patient cooperation under sedation is non-existent. However, if radiographic records were available related data were examined in this study. The evaluation criteria of SSCs were given below.

2.6 Evaluation criteria

The cases were evaluated during the follow-up period in terms of occlusal adaptation, marginal adaptation, and other clinical pathologies, considering the following criteria.

Marginal adaptation: During the evaluation, a dental probe was moved circumferentially along all crown margins. Cases with open, overhanging, or poorly adapted margins were considered unsuccessful in terms of marginal adaptation. Patients with unsuccessful marginal adaptation were recalled for the next follow-up period for re-evaluation.

Clinical examination: Cases showing signs of abscess/fistula formation, tenderness on percussion or palpation, or fracture or loss of SSCs were considered unsuccessful in the clinical examination.

Occlusal adaptation: The evaluation included assessing the presence of maximum cusp-fossa interdigitations (maximum intercuspation) with the antagonist tooth in centric occlusion, and the presence of vertical spacing (height in occlusion) between adjacent and opposing teeth. This evaluation took into account the antagonist tooth in the same arch and the symmetrical tooth in the opposite arch. If an increase in occlusal vertical dimension was observed at the site of SSC placement, it was measured using a digital caliper and recorded for analysis.

Criteria for evaluation:

• Less than 1.0 mm height (<1.0 mm) increase in vertical dimension levels were considered successful.

• More than 1.0 mm height (>1.0 mm) increase in occlusion was considered unsuccessful.

Cases deemed unsuccessful were recalled for re-evaluation in the next follow-up period. Additionally, if the patient was cooperative, photographic/radiographic records were taken during the clinical examination.

2.7 Statistical analysis

The failure and success data for occlusal adaptation, clinical success and marginal adaptation within the specified time periods were presented as number of patients and percentages. Statistical analysis between the examination periods was performed by using Wilcoxon Signed-Rank test. Statistical significance level was set at 5%.

3. Results

Patients who were called for clinical follow-up visits were examined by 2 different researchers in a blind manner, ensuring that these researchers did not influence each other's assessments. Subsequently, the "inter-examiner reliability" level between the two researchers was measured and found to be 0.9, indicating good reliability.

The cases were initially recalled at the first week and examined based on the evaluation criteria mentioned earlier. Table 1 displays the results of marginal adaptation, clinical success, and occlusal adaptation of the subjects for all follow-up periods. Regarding marginal adaptation and clinical evaluations, all included cases exhibited success at each follow-up timepoint (Table 1). Furthermore, successful occlusal adaptation was observed in 83.33% of cases during the first week (Fig. 1). In the marginal adaptation and clinical success evaluations, there were no statistically significant differences between the examination periods (between T1 and T2, between T1 and T3, between T1 and T4) in terms of the number of successful cases ($p = 1.000$, $p = 1.000$ and $p = 1.000$, respectively). However, in occlusal adaptation success, the number of patients who were successful in the initial examination (T1) was statistically significantly lower than the number of patients who were successful in the other examination periods (T2, T3 and T4) ($p = 0.046$, $p = 0.046$ and $p = 0.046$, respectively).

4. Discussion

Dental caries is a public health problem that particularly affects pediatric dental patients [20]. Rehabilitation of decayed primary teeth is necessary for masticatory function, speech and space maintenance. Restoration of dental caries in children is the most difficult process to manage, including various challenges such as behavior management and the need for accurate treatment planning [21].

SSCs are one of the most widely preferred alternatives for restorative rehabilitation of deciduous teeth with severely coronal loss. SSCs offer superior properties to other restorative materials such as amalgam and composites in terms of durability and longevity. In addition, other crown restorative options do not offer the cost-effectiveness, reliability and durability advantages of SSCs when a full coronal crown is required [22, 23].

Challenges in SSC Placement:

Selecting a coronal restoration that effectively covers all surfaces of the crown and provides optimal occlusion is crucial for restoring deciduous teeth with advanced coronal damage. Moreover, inadequate preparation and cementation errors resulting in undesirable positioning and misplacement of SSCs may lead to premature contact. Premature contact and occlusal interference can often lead to undesirable complications such as occlusal trauma, root resorption or endodontic treatment failure [24]. While the significance of this issue has been highlighted in dental literature, limited information is available regarding occlusal changes after SSC placement [25, 26].

TABLE 1. Results of the number of successful cases for marginal adaptation, clinical success and occlusal adaptation in all follow-up periods and statistical comparisons.

	Number of successful cases in the 1st week (T1) (%)	Number of successful cases in the 1st month (T2) (%)	Number of successful cases in the 3rd month (T3) (%)	Number of successful cases in the 6th month (T4) (%)	*p* values
Marginal Adaptation	24 (100%)	24 (100%)	24 (100%)	24 (100%)	T1–T2: 1.000* T1–T3: 1.000* T1–T4: 1.000*
Clinical Success	24 (100%)	24 (100%)	24 (100%)	24 (100%)	T1–T2: 1.000* T1–T3: 1.000* T1–T4: 1.000*
Occlusal Adaptation	20 (83.33%)	24 (100%)	24 (100%)	24 (100%)	T1–T2: 0.046* T1–T3: 0.046* T1–T4: 0.046*

**Wilcoxon Signed-Rank Test.*

FIGURE 1. SSCs placed on the lower (a,b) and upper (c) primary first molars with successful occlusal adaptation.

It is commonly accepted that the dentist clinically controls occlusion by adjusting dental closure after SSC placement [22]. However, this approach is not always practical, particularly during general anesthesia or sedation when it is challenging to close the mouth and control dental occlusion. Similarly, occlusal interference and bite patterns were not assessed in the cases included in this study due to procedural constraints. These constraints may include the presence of a pharyngeal pack, which pushes the tongue forward and makes it difficult to close the mouth, as well as relaxation of the masticatory muscles. Therefore, in the cases included in this study, occlusal assessments were conducted solely with reference to the vertical dimensions and locations of adjacent and opposing teeth. Furthermore, the non-cooperative nature of these patients, who required deep sedation, precluded the use of more complex methods for post-operative occlusal control. Recent evidence has shown a transient increase in vertical dimension in the majority of SSCs placed without occlusion control and adjustment [27]. Because of this, it is recommended to perform occlusal reduction during the preparation procedure for SSC placement to minimize the possibility of occlusal interference. In the vast majority of children, SSCs placed in a high occlusal dimension do not cause problems. However, it is recommended to avoid placing crowns that exceed heights of >1.5 mm. It has been suggested that heights of <1 mm are better tolerated in the majority of cases, with a dentoalveolar compensation mechanism occurring over several weeks. Therefore, in this study, heights of <1 mm were considered acceptable. On the other hand, the placement of an SSC without tooth reduction and preparation, known as the Hall Technique, has become more popular in recent years [28]. Additionally, it has been reported that the unavoidable increase in vertical occlusal dimension and the presence of premature contacts were fully resolved by the end of the first-year follow-up. Re-equilibration generally occurred within 2 weeks [29]. Furthermore, no evidence has been reported to suggest that the placement of SSCs in a high vertical dimension causes occlusal dysfunction or temporomandibular joint disorders [29]. This is attributed to the significant dento-alveolar compensatory capacity in pediatric dental patients [25, 30, 31]. Even with the Hall technique without occlusal reduction, occlusal intercuspation is regained after a few weeks [16–18, 28, 29], suggesting that occlusal intercuspation can be achieved in a shorter time with traditional SSC placement involving occlusal reduction. Since the occlusal reduction was performed in the cases in this study, few cases (16.67%) showed increase in the vertical dimension of occlusion or occlusal interferences was detected even in the early-term controls. Acceptable vertical dimensions in occlusion were observed in the first week in 83.33% of the cases. However, in the occlusal adaptation evaluation, the number of cases who were successful in the initial examination (T1) was statistically significantly lower

than the other examination periods (T2, T3 and T4). This finding suggested that the patients SSCs placed under deep sedation should be followed up not only in the first weeks but at least for the first few months following the operation.

Few studies have evaluated occlusal changes following SSC placement in children. Gallagher *et al*. [25] evaluated changes in maximum intercuspation position after SSC placement in 20 children aged 6–12 years. The authors reported that there was no significant difference between the post-operative 4th week after SSC placement and the preoperative values. Also, the authors emphasized that the maximum intercuspation position was impaired with SSC placement in 35% of cases. However, it was reported that most cases with impaired maximum intercuspation position returned to preoperative status within 4 weeks after placement of SSCs. Gallagher *et al*. [25] also emphasized that younger children have an adaptable masticatory system that changes occur rapidly. Furthermore, the increased adaptability of the condylar structure, mandibular growth/development and the rate of eruption of teeth appear to allow the adaptations required to regain occlusal alignment without the development of various signs and symptoms. Ghadimi *et al*. [31] evaluated the occlusal changes after SSC placement under general anesthesia in 60 children aged 2–7 years using canine overlap measurement. The authors marked the point of contact of the most prominent region of the maxillary and mandibular primary canine before, immediately after, and at the first and second postoperative week. The authors stated that canine overlap significantly reduced immediately after general anesthesia and the mean bite opening size was 0.51 ± 0.22 and 0.50 ± 0.185 mm at the site of the right and left canine, respectively. The authors also reported that these values returned to their normal preoperative state after one week. Alshareef *et al*. [26] evaluated bite patterns before and after restorations under general anesthesia of all teeth of children with severe early childhood caries. The authors concluded that SSC placement significantly improved mastication and the number of force outliers and occlusal interferences increased by 100% in the first week, but decreased to 40% after post-operative one month. Similar to the previously mentioned studies, it was found that SSC restorations performed under deep sedation did not result in a negative alteration in the vertical dimension of occlusion in this study.

It is believed that choosing the preformed crown in accordance with the tooth type and tooth dimensions of the case, considering the reference point the occlusal levels of the opposing and adjacent teeth, and making occlusal reduction during SSC application may be factors that prevent deterioration in the vertical dimensions of occlusion. To ensure adequate clearance for placement and sufficient reduction to accommodate the crown, the clinician should (i) begin by reducing the occlusal surface of the tooth gradually using a fine diamond bur, (ii) aim to achieve a flat, uniform occlusal reduction while preserving the functional cusps and maintaining adequate clearance for the SSC [30]. Occlusal interference or changes in the vertical dimension were not observed in this study, as SSC placement was carried out considering the criteria mentioned above. Other potential factors are believed to have contributed to this successful outcome. Preparing the teeth with knife-edge margins in primary teeth and avoiding chamfer edges adjacent to the gingiva does not prevent the SSC from being embedded under occlusal forces. Although it may appear to be a disadvantage at first glance, it is believed that this factor could be beneficial in resolving occlusal incompatibilities if there is a vertical height in the SSC restoration. Additionally, the thinning of the film thickness of luting glass ionomer cements over time may also contribute to resolving the increase in vertical height observed in the occlusal dimension. Moreover, it is possible to infer that children have a masticatory system in which adaptive changes occur rapidly [25, 26, 29, 31]. It is also important postoperatively to recommend a soft diet and discourage consumption of sticky or hard foods that could compromise the SSC's integrity for a few days to minimize stress on the SSC and the underlying tooth [28–30].

This study had several strengths. The clinical outcomes of the cases presented in this study were considered satisfactory in terms of the occlusal success of SSCs placed under deep sedation. Considering that these patients were clinically non-cooperative, the observed occlusal adaptation even in the first follow-up period under deep sedation conditions, where occlusal checks are limited, indicates promising results for SSC placement under deep sedation.

However, there were also several limitations to this study. Firstly, the retrospective design of the study meant that it did not follow the pre-standardized method steps of a prospective clinical trial. This may have influenced the study findings and results. Secondly, because the study included patients who had previously undergone SSC placement under deep sedation, their lack of cooperation at treatment and follow-up clinic appointments prevented detailed radiographic examinations from being performed at follow-up appointments. Therefore, evaluations were primarily based on basic clinical examinations, which was another limitation.

Additionally, there was no experimental group in this study for clinical or radiographic comparisons. It is recommended for future studies to design comparative studies between patients placed in SSCs under routine clinical conditions without sedation and those included in this study.

Furthermore, confirming these results with radiographic data would have been beneficial, but the level of cooperation of the children included in the study during clinical controls was not suitable for radiography, which is also a limitation.

Moving forward, future studies should investigate the long-term consequences of occlusal changes caused by SSC placement under deep sedation and explore patient satisfaction and its effects on oral health-related quality of life. Prospective clinical studies are needed to investigate and confirm standardized clinical protocols for the placement of SSCs in children treated under deep sedation. Therefore, it is crucial that the results of this retrospective study be validated by further prospective clinical studies that do not have the mentioned limitations.

5. Conclusions

Within its limitations, this study demonstrated that the occlusal adaptation of stainless-steel crowns placed under deep sedation was acceptable even in the immediate postoperative period.

The highly adaptive masticatory system of children is believed to have contributed to these results. It is therefore suggested that acceptable occlusal harmony can be achieved by using adjacent and opposing teeth as a reference during SSC placement. However, further clinical studies are necessary to validate and confirm these findings.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

AUTHOR CONTRIBUTIONS

AD, NSÖ, TB and ŞS—conceived and designed the experiments. AD, MHK, ÇV and ŞS—performed the experiments. AD, ÇV and ŞS—analyzed the data. AD, NSÖ, MHK, ÇV, TB and ŞS—prepared figures and/or tables; authored or reviewed drafts of the article, and approved the final draft.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The institutional ethical committee of Ankara University, Faculty of Dentistry approved the present study (Approval number: 18/13, decision date: 05 December 2022). All the procedures of the study were performed based on the Declaration of Helsinki. This study aimed to perform a retrospective cohort research of all cases in previous year (January 2022–January 2023) whereby stainless-steel crowns were used in treatments given at the pediatric sedation unit at the Ankara University Faculty of Pediatric Dentistry. All the parents of the patients had signed the informed consent forms in the day of the procedure.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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