Trends, Characteristics, and Success Rates of Treatment for Severe Early Childhood Caries Under General Anesthesia: A Retrospective Study in Northwest China

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Background/Objective: *To retrospectively analyze the characteristics, tendencies, and success rates of dental treatments for severe early childhood caries (SECC) under general anesthesia (GA) in in northwest China.* ***Study design:*** *Children diagnosed with SECC were included in this retrospective study. From January 2015 to December 2018, they received dental treatment under GA at Affiliated Stomatology Hospital of Xi'an Jiaotong University. Demographic information, caries status and treatment characteristics were collected from electronic medical record system. Success rates of different treatments at 6-month and 12-month follow up were also analyzed.* ***Results:*** *A total of 846 children (477 male, 369 female) received dental treatment under GA. The case number was increased from 148 in 2015 to 278 in 2018. There were 81.2% and 70.8% of the children participated the 6-month and 12-month follow up. SSC and pulpotomy was the most successful restorations and pulp therapy, with the success rate of 97.09% and 93.98% in 12-month follow up, respectively. The use of crown restorations (including composite resin crown and stainless steel crown) and pulp reservation therapies (including indirect pulp therapy and pulpotomy) were significantly increased while composite resin filling and pulpectomy decreased during 2015 to 2018.* ***Conclusion:*** *There has been an increasing demand for dental treatment under GA for children with SECC in northwest China, with a trend toward younger ages. With better clinical outcomes, crown restorations and pulp reservation therapies were the fastest-growing treatments under GA.*

Keywords: *severe early childhood caries; general anesthesia; retrospective study*

INTRODUCTION

Dental caries in primary teeth is one of the most common chronic diseases, affecting > 560 million children globally[1]. As part of the Global Burden of Disease 2016 Study, a systematic analysis reported that dental caries in primary teeth was ranked 12th among the most prevalent conditions worldwide [1]. The prevalence and severity of dental caries in primary teeth differs across regions and countries, and the situation is less satisfactory in developing than in developed nations. In Southeast Asian countries, such as Cambodia, Laos, and the Philippines, the prevalence of caries in preschool children has been reported to be up to 90% [2]. In China, the 4th National Oral Health Survey revealed that the prevalence of caries in primary teeth among 5-year-old children was 71.9%, which was an increase from 66.0% reported 10 years previously [3].

According to the American Academy of Pediatric Dentistry (AAPD), early childhood caries (ECC) is defined as the presence of ≥ 1 decayed (non-cavitated or cavitated), missing as a result of caries, or filled tooth surfaces in any primary tooth in a child ≤ 71

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months of age [4]. The AAPD also specifies that in children < 3 years of age, any sign of smooth-surface caries is indicative of severe ECC (SECC) [4]. From 3 to 5 years of age, children with decayed, missing (due to caries), or filled teeth (DMFT) with an index score ≥ 4 (3 years), ≥ 5 (4 years), or ≥ 6 (5 years) is diagnosed as SECC [4]. Most ECC and SECC patients first receive dental treatment with the assistance of non-pharmacological behavior management including "tell-show-do", voice control, positive reinforcement, modeling, and protective stabilization [5]. However, these techniques are not absolutely effective in all young patients due to their limited ability to attend and/or cooperate in multiple appointments and complex treatment procedures.

Dental treatment performed under general anesthesia (GA) is generally accepted to be a safe and effective procedure for young patients with SECC [6]. In 1984, more parents preferred non-pharmacological behavior management to pharmacological approaches such as medical sedation or GA [7]. Currently, acceptance of dental treatment under GA is increasing. Parents with negative dental experiences are more willing to choose GA for dental treatment for their children, than treatment using hand-over-mouth and active or passive restraint [8,9]. In China, the dental GA technique began in the late 1990s. The first cases of dental treatment under GA for young patients were performed at the Affiliated Stomatology Hospital of Xi'an Jiaotong University (Shaanxi, China) in August 2014. This hospital was the second institution to provide such treatment in northwest China. However, few studies have examined clinical outcomes following treatment for SECC under GA in Northwest China because this technique has been practiced for < 10 years in this region. Therefore, the objective of the present study was to retrospectively analyze the characteristics, tendencies, and success rates of dental treatments for SECC under GA provided at the Department of Pediatric Dentistry in the Affiliated Stomatology Hospital of Xi'an Jiaotong University between January 2015 and December 2018.

MATERIALS AND METHOD

This retrospective study was based on data collected from an electronic medical records system. The study was approved by the Medical Ethics Committee of the Affiliated Stomatology Hospital of Xi'an Jiaotong University (xjkqll2018-024). The study population included children diagnosed with SECC who underwent dental treatment under GA in the Department of Pediatric Dentistry, Affiliated Stomatology Hospital of Xi'an Jiaotong University between January 2015 and December 2018. Children who fulfilled the following criteria were included: diagnosed with SECC and uncooperative with dental treatment using non-pharmacological behavior management; parents who voluntarily provided informed consent for dental treatment under GA for their children and access to the child's dental records was permitted for this research; and dental records documenting pretreatment, and the 6- and 12-month follow-ups were available. Children with developmental or general diseases, those who underwent GA but not for caries-related problems, such as dental trauma, supernumerary teeth, and short labia or tongue ties, and those whose parents refused the use of their dental records for this study or could not ensure follow-up examinations, were excluded from the study.

Demographic information collected included child's name, sex, and age. During treatment with GA, caries status and individual dental procedures were recorded for each tooth. The decayed, missing, and filled teeth index (i.e., dmft) for primary dentition was used to record caries status. Dental treatments were recorded as restorations, pulp therapies, and extractions of primary teeth. For restorations, composite resin fillings (CRF) and composite resin crowns (CRC) for anterior teeth, stainless steel crown (SSC) for molars, and fissure sealant (FS) were included. Among pulp therapies, indirect pulp therapy (IPT), pulpotomy, and pulpectomy were included. Root canals were filled with Vitapex (Neo Dental Chemical Products Co. Ltd., Tokyo, Japan) after pulpectomy. After pulp therapies, all molars were restored using SSC, while anterior teeth were restored using CRC.

All participants were recalled for clinical and/or radiographic examinations 6 and 12 months after treatment. At these appointments, the outcome of each treated tooth was evaluated. A restorative treatment was considered to be a failure if ≥ 1 of the following conditions appeared: secondary caries; restoration was missing, fractured, or cracked; SSC/CRC was missing or perforated; and/or FS was completely lost. A pulp therapy was considered to be a failure if ≥ 1 of following symptoms emerged: complaints of spontaneous pain including persistent, lingering, or throbbing pain disturbing sleep and preventing regular activity; sensitivity or pain to percussion; presence of an abscess, swelling, or sinus; and/or inter-radicular or furcation pathology revealed by radiographic examination. After re-treatment for a failed tooth, data for this tooth was omitted from further evaluation in the subsequent follow-up. If signs and symptoms appeared between the operation and the first recall, the failure was calculated at the 6-month follow-up. If signs and symptoms appeared between the first and second recall, the failure was be calculated at the 12-month follow-up.

SPSS version 13.0 (IBM Corporation, Chicago, IL, USA) was used for statistical analysis. One-way analysis of variance (ANOVA) was used for quantitative data, such as the number of treated teeth. The chi-squared test was used for qualitative data, such as the success rates of treatments. Differences with $P < 0.05$ were considered to be statistically significant.

RESULTS

General characteristics

Initially, a total of 846 children (477 male, 369 female) met the inclusion criteria. In terms of age, 109 (12.88%) patients were ≤ 3, and 737 (87.12%) were 3–6 years of age. The number of cases increased from 148 in 2015 to 278 in 2018. There was an increase in the proportion of patients ≤ 3 years of age from 2015 to 2018 (14 [9.46%] to 43 [15.47%], respectively) (Table 1).

Caries status and treatment characteristics

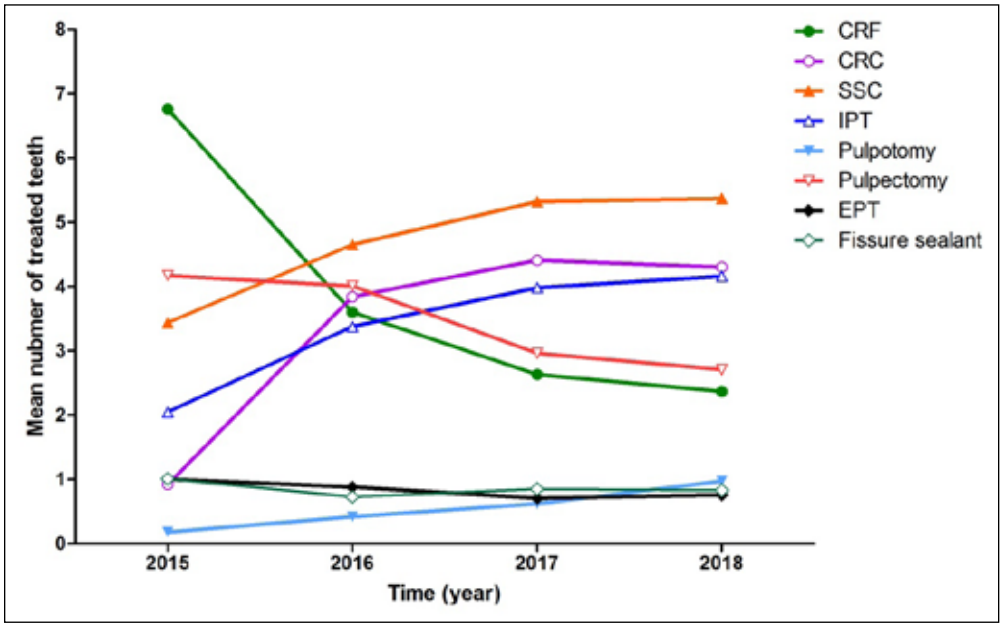
There were 462 (54.61%) patients in the 10–15 dmft group, which was significantly higher than in the other two groups (Table 2). In addition, there was an increase in the proportion of patients in the ≥ 15 dmft group from 2015 to 2018.

The total numbers of teeth with different treatments for SECC under GA, with the mean number of teeth for each patient expressed as mean ± standard deviation, are summarized in Table 3. Initially, CRF and pulpectomy were the most adopted treatments for

Table 1. Demographic characteristics of the study population

	2015 (%)	2016 (%)	2017 (%)	2018 (%)	Total (%)
Gender					
Male	92 (62.16)	98 (49)	122 (55.45)	165 (59.35)	477 (56.38)
Female	56 (37.84)	102 (51)	98 (44.55)	113 (40.65)	369 (43.62)
Age					
≤3 years	14 (9.46)	22 (11)	30 (13.64)	43 (15.47)	109 (12.88)
3-6 years	134 (90.54)	178 (89)	190 (86.36)	235 (84.53)	737 (87.12)
Total	148	200	220	278	846

Fig. 1 Variation tendencies of mean numbers of treatments



CRF=composite resin filling; CRC=composite resin crown; SSC=stainless steel crown; IPT=indirect pulp therapy; EPT= extraction of primary teeth.

Table 2. Distribution of the caries status by year

dmft	2015 (%)	2016 (%)	2017 (%)	2018 (%)	Total (%)
5-10	30 (20.27)	34 (17)	28 (12.73)	43 (15.47)	135 (15.96)
10-15	84 (56.76)	112 (56)	120 (54.54)	146 (52.52)	462 (54.61)
≥15	34 (22.97)	54 (27)	72 (32.73)	89 (32.01)	249 (29.43)
Total	148	200	220	278	846

dmft =decayed, missing, and filled teeth index for primary dentition.

restoration and pulp therapy, respectively. With increasing understanding and awareness of the importance of preserving the vital pulp in primary teeth, IPT and pulpotomy became the first-line treatment for deep caries and teeth without carious pulp exposure, rather than pulpectomy. To prevent marginal microleakage and to enhance the resistance of restorations, SSC was the most popular technique for primary molars. Due to its excellent esthetic outcome, the application of CRC significantly increased since 2016. The extraction of primary teeth and FS demonstrated no significant changes during the study period. Figure 1 illustrates the variations and trends in the mean number of treatments and provides a clearer pattern of how each treatment has changed over the 4 years.

Success rates of dental procedures under GA

Success rates of the different treatments at the 6- and 12-month follow-ups are summarized in Table 4. Some participants were lost to follow-up. Six months after the GA, 687 children participated in follow-up. However, only 599 attended follow up at 12 months. For restorations, SSC was the most successful of all treatments, regardless of the 6-month (98.39%) or 12-month (97.72%) follow-up. Twelve months after treatment under GA, the success rates of resin restorations, including CRF and CRC, were significantly decreased. Nevertheless, the success rate of CRC remained superior to CRF, and this difference was statistically significant. Such a decrease in the success rate did not appear for SSC. The success rate of FS was

Table 3. Treatment characteristics and numbers of treated teeth by year

	2015	2016	2017	2018
CRF	1000(6.76±3.04)[a]	720(3.60±2.74)[b]	580(2.63±2.03)[c]	659(2.37±1.91)[c]
CRC	136(0.92±1.70)[a]	768(3.84±2.42)[b]	970(4.41±2.85)[b]	1196(4.30±2.75)[b]
SSC	510(3.44±1.97)[a]	930(4.65±2.39)[b]	1172(5.32±2.12)[c]	1493(5.37±2.63)[c]
IPT	304(2.05±2.38)[a]	676(3.38±2.66)[b]	876(3.98±3.31)[b]	1158(4.16±3.21)[c]
Pulpotomy	27(0.18±0.48)[a]	83(0.42±0.85)[a]	136(0.62±1.26)[b]	269(0.97±1.56)[c]
Pulpectomy	617(4.17±2.75)[a]	802(4.01±2.87)[a]	652(2.96±2.59)[b]	753(2.71±2.06)[b]
EPT	148(1.00±0.48)[a]	176(0.88±1.68)[a]	156(0.71±1.43)[a]	210(0.76±1.49)[a]
FS	150(1.01±1.71)[a]	146(0.73±1.42)[a]	188(0.85±1.51)[a]	233(0.83±1.47)[a]

The data was present as total number of teeth (mean number of teeth±SD).

CRF=composite resin filling; CRC=composite resin crown; SSC=stainless steel crown; IPT=indirect pulp therapy; EPT= extraction of primary teeth; FS= Fissure sealant

Different superscript letter denotes significant contrast among years for the same treatment (ANOVA test followed by Bonferroni post hoc test, p<0.05).

Table 4. Success rates of restorations and pulp therapy under general anesthesia

	6-month follow up (N=687)			12-month follow up (N=599)		
Treatment	**Teeth**	**Fail**	**Success rate (%)**	**Teeth**	**Fail**	**Success rate (%)**
Restorations						
CRF	2434	237	90.26[a]	2010	332	83.48[a□]
CRC	2511	152	93.95[b]	2205	211	90.43[b□]
SSC	3304	53	98.39[c]	2939	67	97.72[c]
FS	574	36	93.73	504	58	88.49[□]
Pulp therapy						
IPT	2467	126	94.89[a]	2193	154	92.98[a□]
Pulpotomy	405	23	94.32[a]	360	22	93.89[a]
Pulpectomy	2307	67	97.09[b]	1959	271	86.17[b□]

Different superscript letter denotes significant contrast among treatments at the same follow up time point (p<0.05). The success rate of FS was not compared with other treatments of restorations.

□ denotes significant contrast between follow up time points for the same treatment (p<0.05).

CRF=composite resin filling; CRC=composite resin crown; SSC=stainless steel crown; IPT=indirect pulp therapy; EPT= extraction of primary teeth; FS= Fissure sealant.

not compared with other restorative treatments at the same point. The success rate of FS decreased from 93.73% to 88.49%, over the duration of the observation period.

For pulp therapy, pulpectomy yielded the highest success rate at the 6-month follow-up (97.09%), but the lowest at the 12-month follow-up (86.17%). Although the success rates of IPT and pulpotomy were both > 90%, it appears that pulpotomy resulted in better stability because there was no significant difference between the 6- and 12-month follow-up, while IPT demonstrated a significant downward trend.

DISCUSSION

As previously reported in Australia [10] and England [11], tooth extraction is the most common reason for dental treatment under GA, accounting for 63.7% and 80% of procedures in each country, respectively. In Asia, this technique is usually applied as a conservative measure for dental caries treatment [12]. Of 846 children diagnosed with SECC in the present study, the number receiving dental treatment under GA demonstrated an increasing tendency since its introduction, and the number of patients almost doubled from 2015 to 2018. On the one hand, this may be related to increased awareness of oral health care by parents. On the other, this could be attributed to the popularization of the application of anesthesia across medical fields in China [13]. After experiencing or hearing about the advantages of anesthesia, such as painless labor or painless gastroscopy, more parents are permitting dental treatment under GA for their children rather than negative behavior management. It is worth noting that, in a cross-sectional study in 2018 [14], 87% of pediatric dentists in the United States reported using GA in their practices, an increase from 61% in 1999 [15]. This suggests an increasing demand for dental treatment under GA.

The sample in the present study consisted of 56.38% male and 43.62% female children, which was consistent with that of a previous study conducted in Wuhan, China [16]. Most children were between 3 and 6 years of age. However, the number of patients < 3 years of age increased annually. In addition, caries status reflected by the dmft index also exhibited an increasing trend. According to a prospective cohort study, significant improvement in oral health-related quality of life for children diagnosed with ECC lasted for at least 12 months after dental treatment under GA [17]. However, if

children with ECC do not receive timely dental treatment, it would have a negative effect on both the children and their family's quality of life [17]. Accordingly, we agree with recommendations for early intervention of dental caries [18,19].

Despite the lack of definitive conclusions regarding whether reversible or irreversible impairment of the brain could be caused by dental GA, the operative time for young children should, nevertheless, be as short as possible [20]. According to an announcement from the United States Food and Drug Administration on December 14, 2016, sedatives and GA procedures for children < 3 years of age should not be maintained for > 3 h; otherwise, it may affect brain development [21].

Children diagnosed with SECC may require ongoing dental treatment, which would probably increase the risk for failure. Therefore, it is meaningful to analyze the success rates of different treatments to improve outcomes and reduce relapse of dental treatments under GA. In terms of restorations, some studies have reported that SSC and silver amalgam are the most successful restorative treatments [22,23]. However, silver amalgam is rarely used in China, especially in children. In this study, SSC were recommended for carious primary molars with multiple affected surfaces, and were conventionally placed after pulp therapies, unless the parents refused SSC or the children required magnetic resonance imaging examination. Our results demonstrated that SSC performed better than other restorations, with success rates of 98.39% and 97.72% at the 6–and 12-month follow-ups, respectively. As a full-coverage restoration, SSC are wear-resistant, sufficiently solid, and firmly attach to the primary teeth [24]; moreover, there is virtually no risk for recurrent caries [25]. As another full-coverage restoration for anterior primary teeth, CRC also demonstrated a higher success rate than CRF, which is in accordance with a previous study [26]. During the past 5 to 10 years, CRC has been widely used and has gained approval from parents and pediatric dentists [27,28]. In a study by Tate et al. in 2002, the failure rate of CRC was 51%, and the authors pointed out that restoration failures may be related to follow-up time [29]. The higher success rate of CRC in the present study may have two explanations. First, the performance of composite resins and adhesives has clearly improved over the past few years. Second, indications for restoration of the anterior primary teeth are relatively stringent for treatment under GA. Primary teeth with extensive caries and/or are difficult to repair are extracted and provided with space maintainers [30]. We also found that the success rate of CRC significantly decreased from 93.95% to 90.43% in a 1-year follow up, which was probably due to the common characteristics of composite resins. The success rate of FS was not compared with the other three groups. The decline in the success rate of FS was in accordance with our expectations given the abrasion/wear of sealants [17].

In terms of pulp therapy for primary teeth, pulpectomy has been practiced for a long time in China. In this study, only a few cases of pulpectomy demonstrated clinical or radiological failure at the 6-month follow-up; nevertheless, the long-term outcome of pulpectomy was unsatisfactory. In a clinical randomized controlled trial, the clinical success rate of primary teeth filled with Vitapex after pulpectomy was 100% and 80.4% after 6 and 12 months [31], which was consistent with our results. After 18 months, the clinical success rate of pulpectomy further decreased to 71.4% [31]. This may be explained by the complexity of the root canal system of primary teeth, and that the resorption of the material was faster than that of the root canal [32]. The space left by resorption of material supports an environment for bacterial growth and re-infection of the root canal [31,32]. In contrast, the long-term success rate of pulp preservation therapies (i.e., IPT and pulpotomy) for primary teeth was better. It may be difficult to definitively evaluate pulp vitality in an uncooperative child. As a result, complications, such as pulpitis, pain, swelling and even root resorption, may occur after pulp preservation therapy under GA. Our results suggested that complications of pulp preservation therapies were most likely to appear within 6 months. For pulpotomy, the success rate was relatively stable after 6 months. The placement of crowns also improved the success rate of pulp preservation therapies [33].

It is interesting to note that dental procedures and treatment concepts in pediatric dentistry have gradually changed in recent years. After 4 years of observation, we found that the number of teeth with crown restorations increased while those with CRF dropped significantly. Chen et al. also found that, compared with SSC, CRF restorations have significantly decreased since 2006 [30]. In addition, more attention was devoted to the preservation of vital pulp in primary teeth over time. According to the AAPD, pulpotomy is indicated for primary teeth with traumatic or mechanical pulp exposure, or deep caries without irreversible pulpitis symptoms [34]. However, this procedure was rarely performed in the early years in China. Pulpotomy was first performed in the Department of Pediatric Dentistry in the Affiliated Stomatology Hospital of Xi'an Jiaotong University in 2013. The reasons for this may vary. With the popularization of rubber dams, the commercialization of bioceramic materials (such as MTA and IROOT BP PLUS), findings of major disadvantages of pulpectomy, and recognition of the importance of pulp preservation in primary teeth, pulpotomy has become more accepted and gradually popularized, especially in the northwest of China. In the present study, the number of pulpotomies performed under GA increased substantially from 27 in 2014 to 269 in 2018. The changes in treatment concepts were attributed to clinical and basic research, guideline revisions and amendments, and promotions in academic conferences. Finally, with the same goal of increasing the success rates of treatments and promoting oral health in young children, changes to treatment procedures became increasingly accepted by both pediatric dentists and parents.

Some limitations to the present study should be considered, the first of which is its single-center (Affiliated Stomatology Hospital of Xi'an Jiaotong University) design, which may not be sufficiently representative. As such, the results are primarily applicable in Xi'an City, northwest China. Second, the sample size and follow-up were limited. Among the sample, 81.2% and 70.8% of children participated in the 6-month and 12-month follow-up, respectively, which would increase the risk of bias in calculating the success rates of dental treatment. Third, specific reasons for failure were not considered, and no distinction was made between the anterior and molar teeth. These details may have impacted the relevant findings.

CONCLUSION

Based on the findings from this retrospective study, we demonstrated that there has been an increasing demand for dental treatment under GA for children with SECC in northwest China, with a trend toward younger ages. Crown restorations for primary teeth were more successful than composite resin restorations. Pulp preservation therapies yielded better long-term effects than pulpectomy in primary teeth. Finally, crown restorations and pulp preservation therapies for primary teeth were the most employed treatments performed under GA over time.

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