Treatment effectiveness and economic evaluation of different pulp treatments of primary molars: a retrospective study

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Research article

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Abstract

Background This study focused on the primary molars meeting the indications partially overlapping of indirect pulp treatment (IPT), pulpotomy and pulpectomy.

The aims were to compare the effectiveness and cost of these three treatments and apply cost-effectiveness analysis to provide guidance for physicians and parents.

Materials and Methods The subjects were children whose primary molars were treated with IPT, pulpotomy or pulpectomy from May 2014 to May 2015 in the Peking University School of Stomatology. The general information, treatment information and total treatment cost of patients were collected. Tooth survival time, cost and survival time: cost ratio were compared between the IPT group and the pulpotomy group, and between the pulpotomy group and the pulpectomy group.

Results The survival time: cost ratio of the IPT group was 3.56 ± 0.14 d/Yuan, which was significantly higher than the pulpotomy group (1.46 ± 0.056 d/Yuan; $P < 0.001$); which was in turn significantly higher than the pulpectomy group (0.89 ± 0.038 d/Yuan; $P < 0.001$).

Conclusion IPT had the lowest survival time: cost ratio, indicating this procedure was more economical at a 2.5-3-year follow-up compared with pulpotomy. Pulpotomy was found to be more economical than pulpectomy.

Introduction

In the first US Surgeon General's report on oral health in America, published in May 2000, dental caries was listed as the single most common chronic childhood disease [1]. In China, the fourth national oral health survey conducted in 2017 showed that the prevalence rate of caries in 5-year-old children was 71.9%, and the untreated rate was 96.9% [2]. Untreated caries affect around 621 million children globally, which leads to psychological problems and a poor quality of life [3]. Progression of caries has a large impact on children as it can lead to functional and esthetic problems and affect their quality of life. Therefore, the primary objective of pulp therapy is to maintain the integrity and health of the primary teeth and their supporting tissues. Accepted pulp therapy for primary teeth can be divided into two main categories. One is vital pulp therapy (VPT), which is indicated for deep caries and reversible pulpitis of primary teeth. VPT includes indirect pulp treatment (IPT), direct pulp capping and pulpotomy. The other category, pulpectomy, is a root canal procedure for pulp tissue that is irreversibly infected or necrotic [4, 5].

According to the American Academy of Pediatric Dentistry, IPT is indicated in a primary tooth without pulpitis or with reversible pulpitis when the deepest carious dentin is not removed to avoid pulp exposure. The pulp is judged by clinical and radiographic criteria to be viable and able to heal from the carious insult. Pulpotomy is indicated when caries removal results in pulp exposure in a primary tooth with a normal pulp, reversible pulpitis or after traumatic pulp exposure. The coronal tissue is removed and the

remaining radicular tissue is judged to be vital without suppuration, purulence, necrosis, or excessive hemorrhage (that cannot be controlled by a damp cotton pellet after several minutes), and there are no radiographic signs of infection or pathologic resorption. A pulpectomy is indicated in a primary tooth where the radicular pulp shows signs of irreversible pulpitis (e.g., excessive hemorrhage that is not controlled with a damp cotton pellet applied for several minutes) or pulp necrosis (e.g., suppuration, purulence). The roots should exhibit minimal or no resorption [6].

From the indications given above, we can see that IPT and pulpotomy overlap in terms of indications. For teeth with deep carious pulp or reversible pulpitis, IPT and pulpotomy can both be used as treatment. Similarly, both pulpotomy and pulpectomy can be used as treatments when the coronal pulp reaches a critical state. This study only included primary molars, and excluded the anterior primary teeth, because the children treated were too young to cooperate with procedures on these teeth. Thus, this study focuses on the molars which meet the indications partially overlapping of these three treatments. The aims were to compare the cost and treatment effect of IPT, pulpotomy and pulpectomy, and to apply cost-effectiveness analysis. This will provide a clinical reference point for selection of treatment.

Methods

A retrospective study was carried out using data obtained from the Electronic Medical Record (EMR) System.

The study was reviewed and approved by the Biomedical Ethics Committee of the Peking University School of Stomatology (PKUSSIRB-201631127).

Research subjects

The subjects selected for this study were children whose primary molars were treated from May 2014 to May 2015 in the Peking University School of Stomatology. Eligibility of the subjects for this study was determined using the following criteria:

Inclusion criteria: aged 3 to 8 years old; having one or more primary molars treated with IPT, pulpotomy or pulpectomy; adequate pre-operative and post-operative clinical and radiographic examinations; a follow-up interval of less than 1 year; good general condition (Grade I as determined by the American Society of Anesthesiologists).

Exclusion criteria: follow-up intervals longer than 1 year; suffering from autism, epilepsy, or other systemic diseases.

Data collection

All data were gathered based on searches carried out by Caradigm Beijing Technology using the EMR database of the Peking University School of Stomatology. With respect to each treated tooth, the observing truncation time was 3 years after treatment. All the detailed information obtained from the data, and the limitations of the included teeth, are listed below.

1. Basic information: includes name, gender, date of birth, medical record number and general condition.
2. Information obtained from the first visit includes: date, chief complaints, symptoms, clinical and radiographic examination results, teeth position, diagnosis, treatment and treatment procedure of teeth. Molars with spontaneous pain, percussion pain, abnormal mobility and abnormal gingival situation (swollen, fistula, pyorrhea, etc.) were excluded. Radiograph examination found deep caries approaching or involving the pulp with no evidence of periapical pathology, physiological resorption, internal or external resorption, pulp calcification or root resorption in less than a quarter of patients. All teeth were treated according to clinical practice and operation guidelines of pediatric dentistry [7].
3. Details of procedures carried out: Teeth treated with IPT remained the deepest carious dentin over the pulp horn to avoid pulp exposure. In this group, either calcium hydroxide or glass-ionomer cement were used as liner materials. Pulpotomy-treated teeth were sealed to the pulp after complete removal of carious dentine; if pulp exposure was found before or after complete removal of carious dentin, pulp tissue was capped by mineral trioxide aggregate (MTA). Teeth included in the pulpectomy group were those found to have pulp exposure before complete removal of carious dentin. All root pulp was removed and the bleeding amount after pulp exposure was small. The applied root canal filling materials include Vitapex and iodoform-based paste. All the treated molars were immediately restored with either a composite or a stainless-steel crown (SSC).
4. Information obtained during follow-up includes: chief complaints, symptoms of patients and clinical and radiographic examination results.
5. Cost information: direct cost of treatment, which is the fee patients paid for the treatment, was recorded. Every treatment cost of each tooth was obtained from the charge system of the Peking University School of Stomatology. The cost consists of the treatment, anesthetics and radiography, although a special charge was imposed for general anesthesia (GA). The treatment cost for each tooth was CNY 900 (as at 2014/15), which was different from the general out-patient service. Since some of the research subjects were treated under GA, the cost for these patients was calculated according to the general out-patient charge standard. The exchange rate of USD to RMB in 2014 and 2015 was 0.1628 and 0.16159 respectively.

Clinical treatment effects

The following criteria are based on those defined by Casas [8], combined with clinical manifestations:

N: No abnormal clinical manifestations, such as abnormal gingival situation (swollen, fistula, pyorrhea, etc.) or symptoms such as spontaneous pain. No evidence of radiographic change including widened periodontal ligament, periapical or furcation pathological lesion, pulp calcification, internal or external resorption or other pathological manifestations.

H: No abnormal clinical manifestation or symptoms. Radiographic changes associated with normal physiological molar resorption.

P_0: No abnormal clinical manifestation or symptoms. Radiographic changes show a widened periodontal ligament, pulp calcification, internal or external resorption without periapical lesion. Immediate treatment is not required and the condition remains under observation.

P_1: Abnormal clinical manifestation or symptoms such as spontaneous pain relating to pulpitis. No evidence of radiographic change.

P_2: Normal and abnormal clinical manifestation and symptoms. Radiography shows periapical or furcation pathological lesion, with or without internal and external resorption. Root canal treatment or tooth extraction is required.

P_3: Primary teeth premature loss, no eruption of succedaneous tooth or root length of succedaneous tooth is less than ½ of normal succedaneous tooth.

This study defined success as the clinical and radiographic features of the tooth meeting the criteria of N, H and P_0. If a mild defect of the crown was found at follow-up which was restorable by resin filling or SSC with no obvious pulp or periapical symptoms, it could also be regarded as a success. A failed treatment was when the clinical and radiographic features met P_0, P_1, P_2 or P_3. We took survival time of each tooth to indicate treatment effect, and it was calculated as the period between first and last visit time in days. The duration between first visit and failure time was taken as the survival time of a failed treatment.

In this study, the radiograph was independently assessed by two pediatric dentists. One of them has 22 years of clinical experience, while the other one has 4 years of clinical experience. In case of disagreement, the two dentists would negotiate to reach a final decision. Before assessing the x-ray films, the two evaluators carried out calibration exercises. Sample x-ray films were taken after IPT, pulpotomy and pulpectomy treatment, and were not included in the research data. The evaluators assessed these x-ray films under standardized viewing conditions individually and independently, and afterwards a reliability test was performed based on the result. Two weeks after the preliminary assessment, one of the evaluators reevaluated one of the subsets, to calculate internal reliability. Consensus agreement between reviewers was obtained, with a kappa score of 0.913.

Cost-effectiveness analysis

This study calculated the cost of the three treatments based on the charge system of the Peking University School of Stomatology. When carrying out cost-effectiveness analysis, we took survival time in days per yuan spent to maintain health of the teeth (d/Yuan). Taking each tooth as a unit, we calculated and compared the survival time: cost ratio of the three groups, as shown in Fig. 1.

Statistical analysis

All analyses were performed using IBM SPSS statistics version 22.0 (IBM, Armonk, NY, USA). An analysis of variance (Weltch) and a Chi-square test were performed to compare the baseline data. A Kaplan-Meier survival analysis of IPT, pulpotomy and pulpectomy was used to compare the survival time and survival

time: cost ratio of each treatment. An analysis of variance was conducted to compare the cost of each treatment. A log-rank test was conducted to determine if groups were significantly different. Graphical representations of survival were produced for all groups using the Kaplan-Meier method. $P < 0.05$ (two-tailed) was considered statistically significant.

Results

Basic information (Table 1)

A total of 430 teeth was included, of which 119 were treated by IPT, 203 by pulpotomy and 108 by pulpectomy. A total of 262 patients was included: 84 for IPT, 115 for pulpotomy and 63 for pulpectomy. No significant difference was found in terms of gender or age between the three groups of patients ($P > 0.05$). However, there was a statistically significant difference in terms of treatment methods between the three groups ($P < 0.001$). The follow-up condition of each group is shown in Fig. 2.

Table 1
basic information of patients included in the three groups

Group	Number	Gender (n, %)		Age (y)	Treatment methods (n, %)	
		Boy	Girl		GA	Out-patient
IPT	84	45 (53.6)	39 (46.4)	4.66 ± 1.34	1 (1.19)	83 (98.81)
Pulpotomy	115	57 (49.6)	58 (51.4)	4.75 ± 1.20	54 (53.9)	61 (46.1)
Pulpectomy	63	24 (38.1)	39 (62.9)	4.60 ± 1.05	44 (79.5)	19 (20.5)
F/X^2 value		3.632[b]		0.370[a]	79.505[b]	
P value		0.163		0.691	0.000	
[a] F value, [b] X^2 value						

Comparison between the IPT and pulpotomy groups

The cost of treatment per tooth in the IPT group (324.12 ± 65.27 Yuan) was significantly lower than the pulpotomy group (908.80 ± 147.88 Yuan; $P < 0.001$). There was no difference in terms of survival time of teeth between the IPT group (1017.75 ± 34.09 d) and the pulpotomy group (1013.62 ± 14.09 d; $P = 0.115$). The survival time: cost ratio was significantly higher in the IPT group (3.56 ± 0.14 d/Yuan) than the pulpotomy group (1.46 ± 0.056) d/Yuan; $P < 0.001$; Table 2).

From the follow-up condition of the teeth in each group (Fig. 2), we can see that in the first year of follow-up, nine teeth had failed treatment in the IPT group, which accounted for 32.1% of the total failure rate. In contrast, only three teeth in the pulpotomy group failed treatment, accounting for 8.8% of the total failure.

From this we can conclude that the probability of failure within 1 year of IPT was significantly higher than pulpotomy or pulpectomy (P = 0.004). That is to say, although the survival time: cost ratio of IPT was significantly higher than pulpotomy, the failure rate within 1 year of treatment was also significantly higher. Looking back into the cases, it was found that the nine failed teeth in the IPT group were subsequently treated with pulpectomy. We added the subsequent pulpectomy cost of the nine failed teeth to the total cost of treatment and compared this with the pulpotomy group. The results showed that the survival time: cost ratio of the IPT group was 3.53 ± 0.143 days/yuan, still significantly higher than the pulpotomy group (P < 0.001).

Table 2
comparison between the IPT and pulpotomy groups

Group	Number	Treatment cost (Yuan)	Survival time (d)	Survival time: cost ratio (Yuan/d)
IPT	119	324.12 ± 65.27	1017.75 ± 34.09	3.56 ± 0.14
Pulpotomy	203	908.80 ± 147.88	1013.62 ± 14.09	1.46 ± 0.056
F/X^2 value		183.683[b]	2.488[a]	20.153[a]
P value		0.000	0.115	0.000
[a] X^2 value, [b] t value				

Comparison between the pulpotomy and pulpectomy groups

The cost of treatment per tooth was significantly lower in the pulpotomy group (908.80 ± 147.88 Yuan) than the pulpectomy group (1107.78 ± 115.09 Yuan; P < 0.001). Survival time of teeth in the pulpotomy group was significantly higher (1013.62 ± 14.09 d) than in the pulpectomy group (887.97 ± 24.21 d; P < 0.001). The survival time: cost ratio was significantly higher in the pulpotomy group (1.46 ± 0.056 d/Yuan) than the pulpectomy group (0.89 ± 0.03 d/Yuan; P < 0.001; Table 3). In pulpectomy group three teeth failed treatment, accounting for 6.3% of the total failure. Compared with the pulpotomy group, the probability of failure within 1 year of pulpectomy showed no significant difference (P < 0.001).

Table 3
Comparison between the pulpotomy and pulpectomy groups

Group	Number	Treatment cost (Yuan)	Survival time (d)	Survival time: cost ratio (Yuan/d)
Pulpotomy	203	908.80 ± 147.88	1013.62 ± 14.09	1.46 ± 0.056
Pulpectomy	108	1107.78 ± 115.09	887.97 ± 24.21	0.89 ± 0.038
F/X^2 value		36.873[b]	25.478[a]	65.651[a]
P value		0.000	0.000	0.000
X^2 value, [b] t value				

Discussion

Economic evaluation (EE) studies have been undertaken in dentistry since the late 20th century as economic data are useful to policymakers to develop guidelines and set future directions for oral health services [9]. EE is a systematic analysis that considers all costs and outcomes associated with healthcare interventions, and can be defined as the 'comparative analysis of alternative courses of action in terms of their costs and consequences' [10, 11]. EE studies have been widely used in healthcare systems for the assessment of various programs, including those focused on prevention, diagnosis and treatment [12]. Stephen and Campbell first applied EE to dentistry in 1978, when they conducted a three-year cost-benefit analysis of fluorinated tablets in a Scottish school [13]. More recently, EE has been used in endodontic treatment [14], periodontal treatment [15] and prosthodontic and implant treatment [16, 17]. The results of the fourth national oral health epidemiological survey of China, released in 2015, showed that the prevalence rate of caries in the primary teeth of 5-year-old children was 71.9%, and that of the permanent teeth of 12-year-old children was 34.5%. This high rate made research in China a priority. A more economical treatment method for children's oral diseases can effectively increase treatment rate and improve the status of children's oral health. The innovation of this study is the combination of cost and clinical effect, which allowed us to find a method that was not only more effective but also more economical for primary molar treatment.

This clinical investigation was conducted to compare the treatment effect and cost of IPT, pulpotomy and pulpectomy. It included a cost-effectiveness analysis focused on the molars meeting the indications partially overlapping of these three treatments to compare the cost, survival time and survival time: cost ratio. Comparing IPT with pulpotomy, IPT had a significantly lower survival time: cost ratio and was therefore more economical during the 3-year follow up although there was no significant difference in survival time. From this, we can suggest that IPT seems to be a more economical choice for primary molars with deep caries. In addition, after analyzing the teeth that failed 1 year after IPT, we found that seven of the nine failed teeth were due to subsequent symptoms of pulpitis or even periapical

inflammation. During the pulpotomy, dentists can judge the condition of pulp inflammation according to the pulp traits and hemorrhage, and then determine whether the tooth is suitable for treatment with pulpotomy. However, during IPT, dentists cannot directly observe the pulp state, and there is no gold standard for determining this in deciduous teeth in clinical practice for IPT. The choice of treatment methods requires a comprehensive consideration of medical history, clinical examination and radiographic examination. The identification of deep caries and pulpitis in primary teeth is difficult for the pediatric dentist, and is the main reason why the failure rate of the IPT group was significantly higher than the other two groups within 1 year. However, although the probability of failure after IPT was significantly higher than after pulpotomy and pulpectomy, the survival time: cost ratio of IPT was still significantly higher than pulpotomy after including the cost of subsequent pulpectomy. This suggests that IPT should be used as much as possible when the pulp is in good condition to achieve better therapeutic effects and cost savings in primary molars.

Compared with pulpectomy, pulpotomy showed a significantly higher survival time and survival time: cost ratio, indicating that it was more economical. This suggested that for primary molars whose coronal pulp is in a critical state, pulpotomy can achieve better therapeutic effects and cost savings.

Previous studies that compared the three treatments looked at differences in clinical effects, and this is the first to evaluate them economically. The success rate of MTA pulpotomy is considered to be between 91% and 100% for 12–38 months, and the success rate for IPT for 6–50 months is approximately the same: between 90% and 95% [18]. Other studies, although not directly comparing IPT and MTA pulpotomy, suggested that IPT can achieve a survival rate of 96% in 3 years and MTA pulpotomy can achieve a survival rate of 95% in 2 years; these are both considered high survival rates [19, 20]. A 2017 study concluded that the success rate of MTA pulpotomy and Vitapex pulpectomy was 90% and 79%, respectively, a statistically significant difference [21]. Most previous studies used survival rate as a valuation index. In this study, although survival time was used as an evaluation index for clinical effects, the results were essentially consistent with previous studies that found no significant difference between the clinical treatment effects of MTA pulpotomy and IPT; however, pulpotomy was significantly better than pulpectomy. The advantage of using survival time is that we can combine treatment effects with costs and conduct health economics assessments, which is the main purpose of this study.

However, there were some limitations in this study. First, although the number of children attending our department is large, regular follow-up is limited, resulting in a limited sample. Secondly, the results of this study can only objectively reflect an area of equal economic level in China. It does not reflect the actual situation of other hospitals, not to mention other regions and countries. If this conclusion is extended to other regions or countries, multi-center and larger studies are needed. Finally, there were significant differences in treatments and restoration methods among the groups. Children included were treated under GA or as out-patients and molars were restored by resin filling or SSC. These differences may have affected the results. However, another study by our group, which selected subjects using the same database, found that different treatments and restoration methods had no impact on survival after

treatment [22]. Therefore, in this study we assumed the differences in treatment and restoration method had no significant impact on the results.

Conclusions

IPT has a significantly lower survival time: cost ratio, indicating it was more economical 2.5-3-years post-treatment compared with pulpotomy. Pulpotomy was found to be more economical than pulpectomy.

Declarations

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Statement of Ethics: no applicable

Disclosure Statement: no applicable

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Author Contributions:

All authors have made substantial contributions to conception and design of the study. Bin Xia has been involved in the conception or design of the work. Ziyi Zhang have been involved in data collection and data analysis. Sun Zhang, Wenli Ma and Guili Dou have been involved in data collection. Ziyi Zhang and Bin Xia have been involved in drafting the manuscript and revising it critically. All the authors have given final approval of the version to be published.

Conflict of interest: The authors declare that there are no conflicts of interests regarding this article.

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Figures

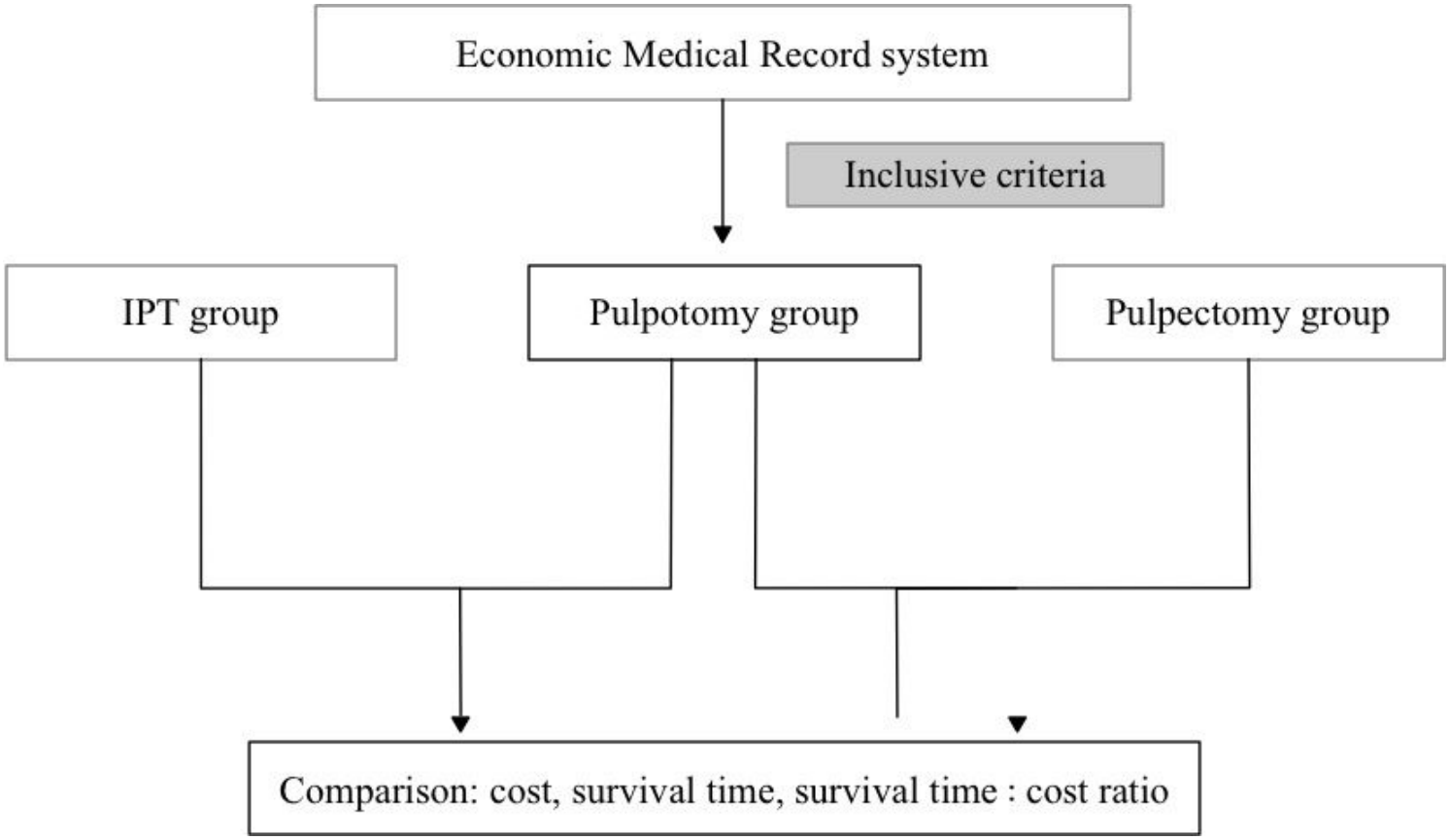

Figure 1

flowchart of the cost-effectiveness analysis

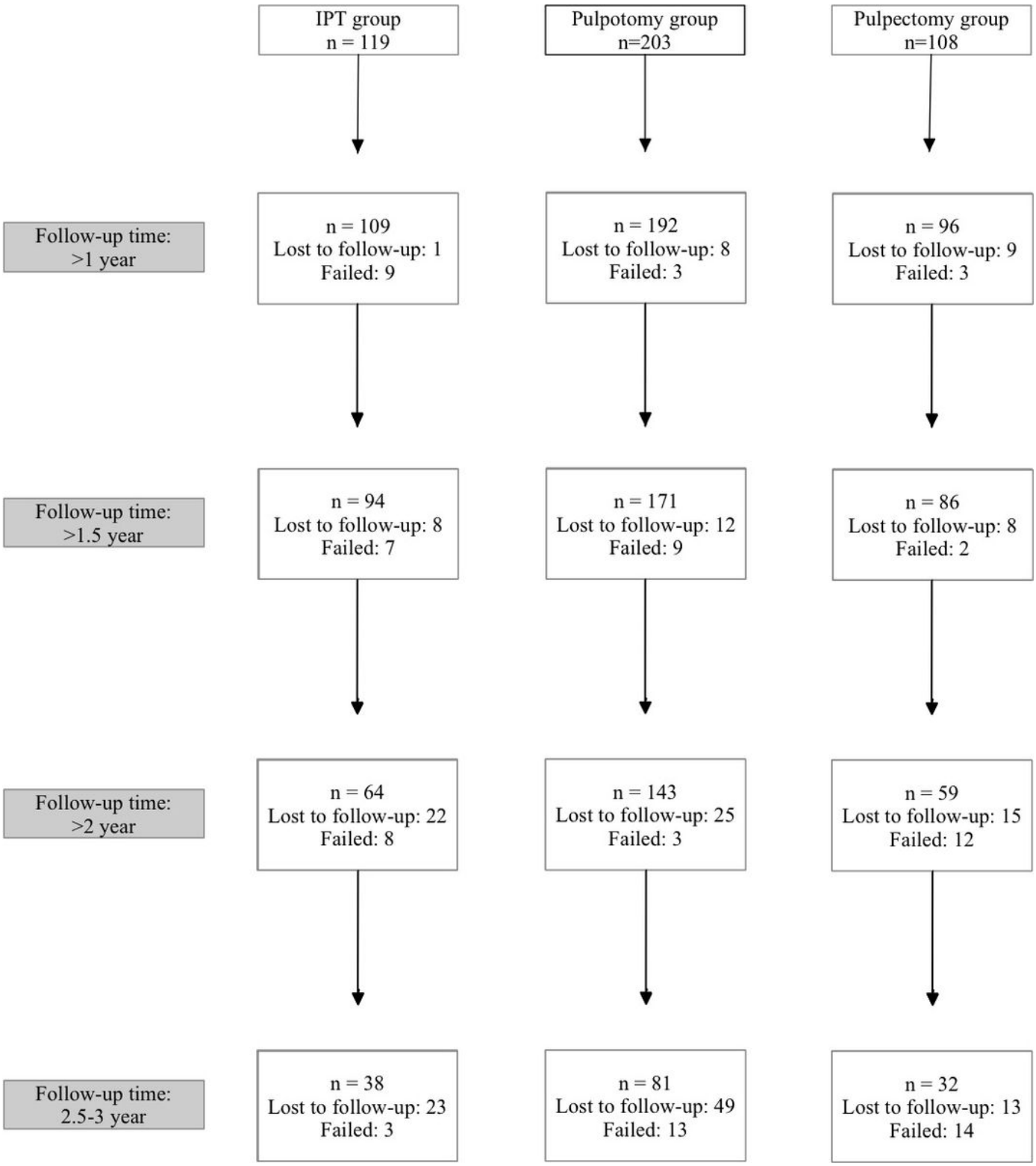

Figure 2

follow-up condition of each group

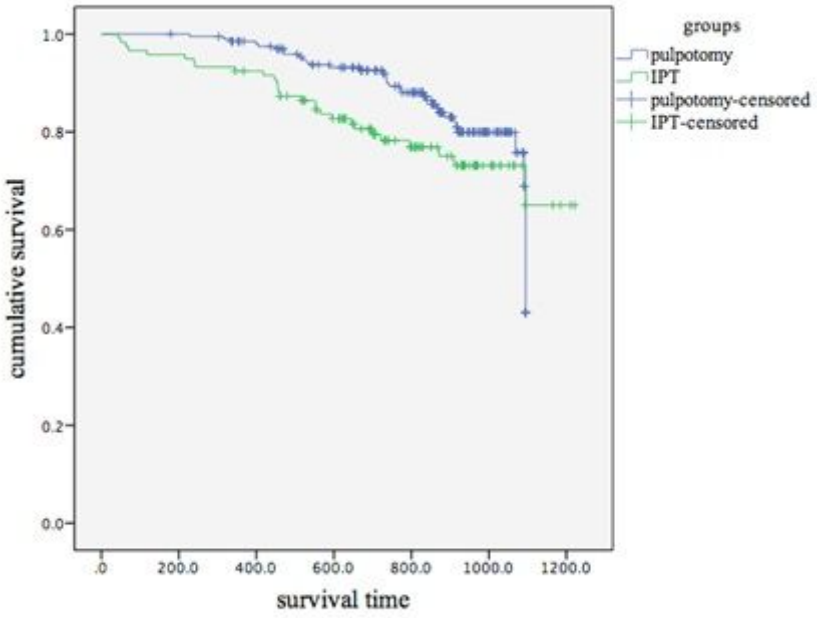

Figure 3

the Kaplan-Meier survival analysis of survival time between IPT and pulpotomy

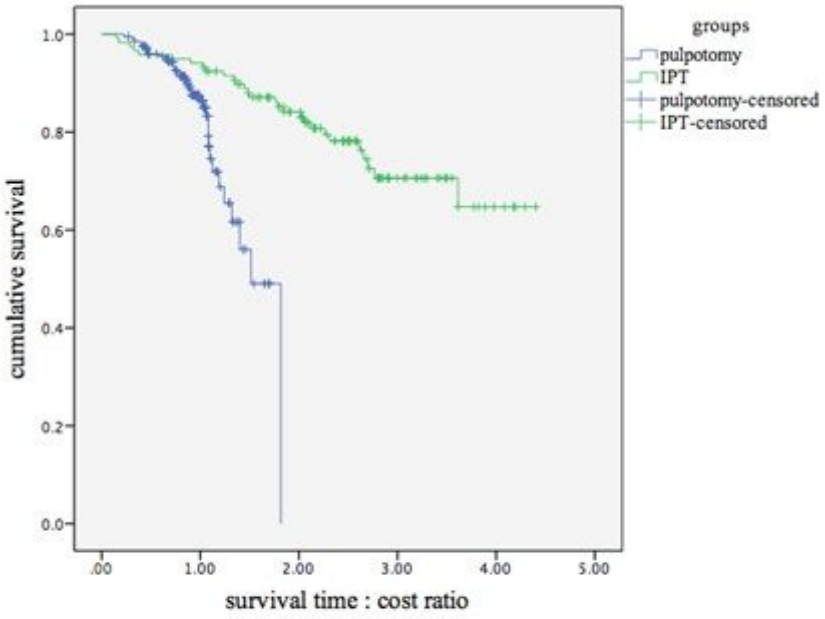

Figure 4

the Kaplan-Meier survival analysis of survival time: cost ratio between IPT and pulpotomy

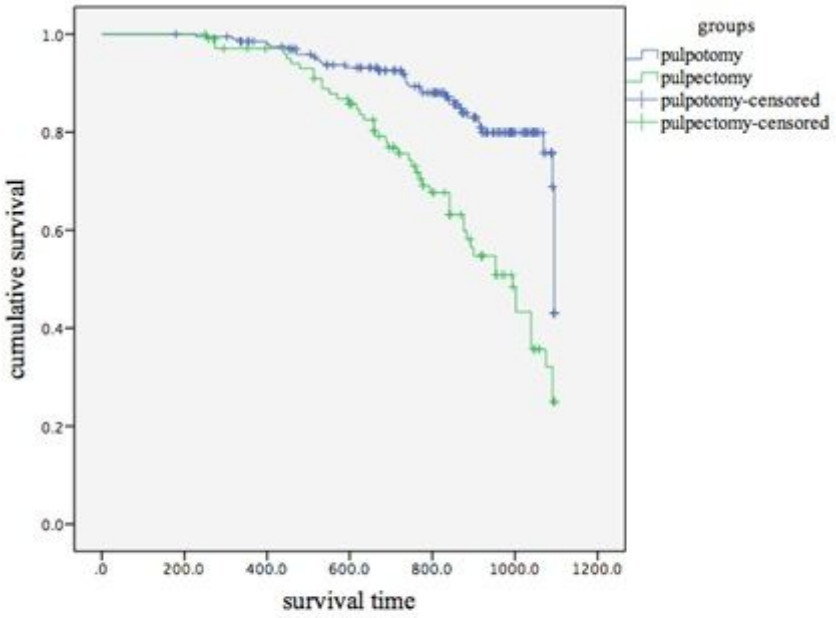

Figure 5

the Kaplan-Meier survival analysis of survival time between pulpotomy and pulpectomy

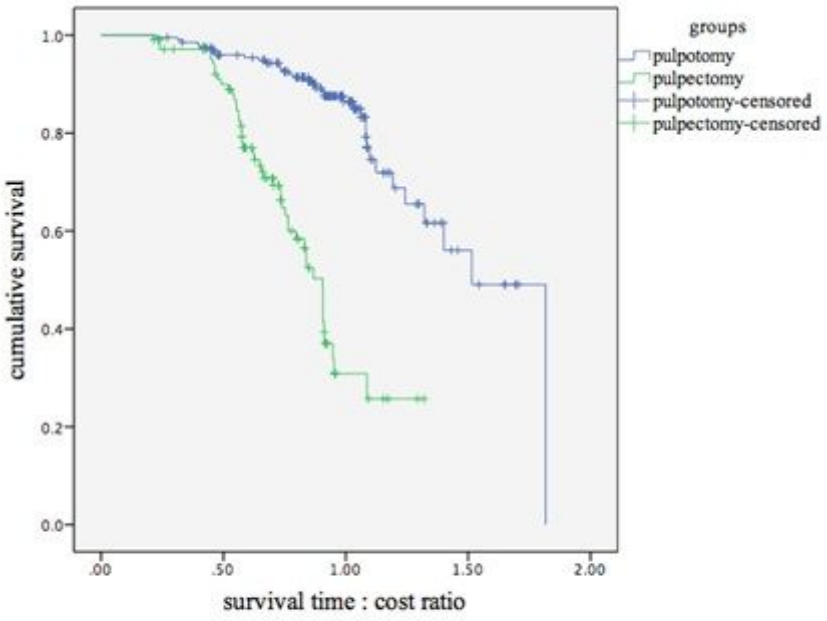

Figure 6

the Kaplan-Meier survival analysis of survival time: cost ratio between pulpotomy and pulpectomy