Permanent teeth pulpotomy survival analysis: retrospective follow-up

Gustavo Golgo Kunert, Itaborai Revoredo Kunert, Luiz Cesar da Costa Filho, José Antônio Poli de Figueiredo

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A B S T R A C T
Objectives: The aim of the present study is to evaluate risk factors influencing the success rates of pulpotomies both in young and adult populations.

Methods: Pulpotomies (n = 273) performed by a single endodontic specialist were analyzed, and data on success rates were collected. Additionally, possible explanatory variables were noted such as: age, gender, clinical findings (teeth, type of restoration after pulpotomy), radiographic findings (dentin bridge formation) and systemic conditions. The follow-up period varied from 1 to 29 years, and the results were analyzed by Kaplan–Meier survival curves and also by Cox regression.

Results: Age at the time of pulpotomy ranged from 8 to 79 and had not influenced the success rates (p = 0.35). The formation of dentin bridge had a strong protective effect (hazard ratio—HR = 0.16, p < 0.001). The prosthetic crown restorations following pulpotomy had the smallest failure rate, and amalgam has not increased the risk of failure significantly in relation to prosthesis. Resin composite restorations following pulpotomy increased in 263% the risk of failure (HR = 3.63, p < 0.001).

Conclusion: This study allowed inferences that pulpotomy may be a successful treatment at any age, and not only for young permanent teeth. It was also possible to conclude that the use of direct composite restorations following pulpotomies is associated with higher failure rates.

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1. Introduction

Pulp conservative treatments are options available to general dentists, both for deciduous and permanent teeth, and among therapies, pulpotomy is identified as one of the most effective [1–4]. The limited adoption of such technique in routine dental care needs to be revisited. Among the concerns stated, there is the possibility of dental resorption [5] or root canal calcification [1], which could jeopardize future endodontic treatment leading to tooth loss. On the other hand, some classic studies from de Sousa and Holland [6] and Holland and de Sousa [7], and also more recent research [1–4], have shown that pulpotomies have a success rate between 85% and 94%.

Studies such as Camp [8] contraindicate pulpotomy when there is spontaneous pain, which would suggest lack of tissue reaction ability. On the other hand, several other authors [4,9,10] have shown success following pulpotomy even when the clinical symptoms were of irreversible pulpite. This brings up the debate as to what the actual situations are for success or failure of this technique.

It can be verified that the minimal use of is not due to possible technical difficulties, but perhaps to lack of incentive and/or a lack of clinical research that considers diagnostics, outcomes and follow-up [11]. There are time lapses and scarce long-term clinical databases for scientific research on pulpotomy, and this generates uncertainties about the clinical and radiographic behavior of pulpotomies and also about the predictability of such technique.

There is little conclusive clinical data on a long-term basis that considers clinical and systemic risk factors along with pulpotomy. Clinical information, such as pain symptoms and dentin bridge formation, or the influence of material selection on the restoration after pulpotomy, and also the possible interference of systemic risk factors (smoking, diabetes, hypertension, cardiopathy, and others) have motivated the present investigation.

This study has aimed to understand the clinical and radiographic behavior of 273 pulpotomies, with updated follow-up (from 1 to 29 years), performed by a single operator, and also to understand the risk factors on pulpotomy’s survival rates.
2. Materials and methods

This research was performed according international guidelines on research ethics, and the Brazilian research ethics committee under the number 14138413.8.0000.5336 approved it. All participants of this study signed a written informed consent.

Information from clinical records and radiographs was extracted from certified digital database from a single endodontic specialist practice from the beginning of the digital records in 1975 through 2014. Data on clinical, systemic and radiographic factors were collected, and also clinical recall was performed to determine an updated success rate on 273 permanent teeth pulpotomy cases (age range: 8 to 79 years old at the time of the procedure—Table 1). All cases were diagnosed, executed and followed by a single endodontic specialist throughout its career. Pulpotomy was selected as treatment based on clinical aspect of the dental pulp: (1) the tissue should be with adequate consistency (not being jelly or liquefied); (2) color presentation should be red or pink; (3) bleeding should follow cutting (lack of bleeding or color presentation as too light or cyanotic led to pulpectomy and conventional root canal treatment) [6,7] regardless of the pain diagnosis (with or without pain). Pure calcium hydroxide powder was selected in all cases as the pulp capping material regardless of the age of the patients.

The cases were not accidental pulp exposures. All patients were referred to the clinic for endodontic treatment and the specialist chose to perform pulpotomy as the final treatment whenever consistency and bleeding patterns allowed.

Cases were selected for treatment with pulpotomy according to clinical examination, in which there was a need for endodontic intervention but with no restorability issues. Periapical and bitewing radiographs were performed. Pulp sensitivity tests, until the late 80’s, were conducted with ice stick and electrical test (Pulp Test, Pelton & Crane Company, North Carolina, USA). Later, thermal test with cooling sprays (–20, Aerojet, Rio de Janeiro, RJ, Brazil) were used.

Patient was anaesthetized and isolation with rubber dam was followed by removal of infected carious dentin and thorough irrigation with distilled water. With a new and sterilized bur, access was performed and coronal pulp was removed with a sharp bladed curette. Bleeding was washed away with distilled water until hemorrhage stopped. Under clear light, the aspect of the remaining pulp was assessed. If normal, a cotton pellet embedded in corticosteroid-antibiotic paste (Otozporin™, FQM, Rio de Janeiro, RJ, Brazil) was accommodated in contact with the surface of the remaining radicular pulp during five minutes. Then, washing with distilled water and drying with sterilized cotton pellet were followed by gentle placement of calcium hydroxide powder (Carlo Erba, São Paulo, SP, Brazil) with a sterilized amalgam carrier in close contact with the surface of the pulp. Care was taken to avoid pressure and load in this phase. Over the powder Dycal™ (Dentsply, Petrópolis, RJ, Brazil) was placed and then a temporary restoration with IRMTM (Dentsply, Petrópolis, RJ, Brazil) or glass ionomer (Vidron R, SS White, Rio de Janeiro, RJ, Brazil) (Fig. 1).

Forty-eight hours following pulpotomy, patient was back for consultation and signs and symptoms were assessed. If everything were OK, patient was referred back to the dentist for final restoration, and scheduled for the first follow-up radiograph and clinical analysis 90 days following procedure.

In a second phase, the patients were contacted and invited to the practice for a new and free appointment to re-evaluate and update the clinical and radiographic condition of the pulpotomized teeth by a second and independent endodontic specialist. From a total of 567 pulpotomies, we could reach 281 patients and only 8 (2.85%) declined to participate. A number of 236 patients have changed phone number and address and we could not reach them (Table 2). Thirteen died, and 36 cases were performed less than one year before analyses and were not included. The reassessments were done according to the guidelines from the European Society of Endodontology [12]. Direct pulp capping and pulp amputation should be assessed no longer than 6 months postoperatively and thereafter at regular intervals. The following findings indicate favorable outcome: normal response to pulp sensitivity tests (when feasible), absence of pain and other symptoms, radiological evidence of dentine bridge formation, radiological evidence of continued root formation in immature teeth, absence of clinical and radiographic signs of internal root resorption and apical periodontitis, and risk factors data and success criteria were determined [12–15].

Teeth under analysis were considered together with periapical tissues, and determination of success and failure were defined as follows:

Success: lack of periapical radiolucency or widening of periodontal ligament apically; no pain following vertical or horizontal percussion; radio-surgical evidence of dentin bridge; lack of clinical or radiographic signs and symptoms of root resorption or apical periodontitis; positive response to sensitivity test, whenever possible.

Failure: presence of sinus tract; presence of periapical radiolucency; pain following percussion tests; clinical or radiographic signs and symptoms of root resorption or apical periodontitis; radiological widening of periodontal ligament; radiographic appearance of bone disturbance or loss.

Cases treated less than one year before the beginning of this study were excluded from our analyses. Minimal time of follow-up was 1 year and the maximum went up to 29 years (average follow-up time 4.75 year ± 5.96 years). Table 2 shows how the 273 pulpotomies were selected out of 567 cases.

Data was recorded in a Microsoft Excel (Microsoft Corp, Redmond, WA) database, and the following variables were collected: record number, gender, birth date, tooth number, pulpotomy date, age at the conclusion of the pulpotomy, number of appointments required to finish the pulpotomy, date of the last reevaluation on the pulpotomized teeth, determination of the success criteria (success or failure) of the pulpotomy, data of the last visit with successful pulpotomy or date of the failure (if this was the case), presence or absence of denting bridge formation detectable on the X-rays, failure cause (if was the case), systemic variables (smoking status, diabetes, hypertension, cardiopathy, and others), type of lining material (zinc phosphate, glass ionomer or other material), type of restoration after pulpotomy (prosthetic crown, amalgam or resin composite).

2.1. Statistical analyses

Initially, the survival rates of the pulpotomized teeth were evaluated and described by Kaplan–Meier curves. The evaluation of the risk factors was performed by Cox proportional-hazards regression in two ways: univariate analysis (non-adjusted model) and multivariate analysis (adjusted model). The Cox regressions results were presented by the hazard ratio coefficient (HR) and its respective 95% confidence interval (95% CI). For the specific analysis of tooth fracture occurrence, Fisher exact test was

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Age distribution at time of the pulpotomy.</th>
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<tbody>
<tr>
<td>Number of cases</td>
<td>14</td>
</tr>
</tbody>
</table>
performed. The adopted level of significance was 5%, and the tests were carried out with SPSS 20.0 (SPSS Inc., 2011, Chicago, IL) statistical package.

3. Results

From the total of 273 pulpotomy cases, there were the following success rates over the years: 1 year, 89% success; 2 years, 83%; 3 years, 81%; 4 years, 76%; 5 years, 75%; and 10 years, 63% (Figs. 2–4 show X-rays of typical long term successful pulpotomy cases).

There was no statistical significance for systemic risk factors such as: smoking status, hypertension, cardiopathy or other

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**Table 2**

<table>
<thead>
<tr>
<th>Case selection and drop outs.</th>
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</thead>
<tbody>
<tr>
<td>Total pulpotomies</td>
<td>567</td>
</tr>
<tr>
<td>Pulpotomies included in the study</td>
<td>273</td>
</tr>
<tr>
<td>Pulpotomies not included in the study</td>
<td>294</td>
</tr>
<tr>
<td>Reasons for exclusion: Cases performed less than one year</td>
<td>36</td>
</tr>
<tr>
<td>Unable to contact patient (change of phone number or address)</td>
<td>237</td>
</tr>
<tr>
<td>Death</td>
<td>13</td>
</tr>
<tr>
<td>Refusal to come to practice for follow-up</td>
<td>8</td>
</tr>
</tbody>
</table>

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**Fig. 1.** Pulpotomy clinical protocol: (a) remaining pulp normal clinical aspect; (b) calcium hydroxide powder placement; (c) DycaTM lining placement; (d) glass ionomer temporary restoration.

**Fig. 2.** Female patient; 19 years follow-up; diagnostics: pulpitis in the first left upper molar; pulpotomy performed at the age of 44 years old. (a) initial periapical X-ray; (b) initial bitewing X-ray; (c) 90 day follow-up; (d) periapical X-ray after 19 years follow up; (e) bitewing X-ray after 19 years follow up (white arrows show dentin bridges formation).
systemic diseases (Table 3). Also, age, gender and number of appointments to conclude the pulpotomy were not significant risk factors (Table 3).

The detection of dentin bridge formation after the pulpotomy is a strong indicator of success, and it is a significant protection factor for failure (Table 3 and Fig. 5). In our results, it is estimated by Cox regression that there was 84% less failure when dentin bridgewas
detected in the X-rays in relation to the group without dentin bridge formation.

In terms of the success rate of the pulpotomy in relation to the type of final restoration, the prosthetic crown was considered the best material followed in a descendent order by amalgam restoration and resin composite (Table 4 and Fig. 6).

Some failure cases were due to tooth fracture rather than failure of the pulpotomy technique. The occurrence of tooth fracture in relation to the final restoration also demonstrated an advantage to prosthetic crown, followed by amalgam restoration, and the worst performance came from resin composite restorations.

4. Discussion

Pulpotomy as a definitive technique has faced controversial opinions in the endodontic scientific literature [1–5]. Although several studies have pointed to pulpotomy as a safe technique in relation to the pulpectomy due to its consistent success rates in survival analysis studies [16–20]. In our research we found success rates up to 89% in the first year, decreasing to 63% by the 10th year. Those rates are in accordance with the studies of Marghalan et al. [17] and Yıldız and Tosun [21], which found similar rates even with different lining and restorative materials, and also in relation to deciduous and permanent teeth.

One might ponder the right moment to perform the pulpotomy technique, because the long-term studies have been performed in different age ranges such as children [22], young adults [23] and middle-aged adults [16], and those age differences among the studies leave room to contest the most adequate age to perform the pulpotomy technique. In our study, ages ranged from 8 to 79 years old, and age was not considered a risk factor (Tables 1 and 3). As in the previously cited studies [5,16,17], ours did not consider age a contraindication even among the elderly.

This led us to question the influence of other systemic factors, which might influence pulpotomy success rates. In our study, the following factors have also not influenced the survival rates for pulpotomy: gender, smoking status, presence of hypertension, presence of any cardiopathy, presence of other systemic conditions as a whole (hepatitis, diabetes, HIV positive). No systemic illnesses were found to be associated with pulpotomy success rates, but more studies are necessary to determine which diseases may impair pulp healing and response; there are many situations that were not present in our patients (such as oncological treatments and other more rare diseases), and also for many situations we did not have an adequate number for statistical analysis.

Our data suggests, from a clinical point of view, that there is no difference in success rates in performing the pulpotomy in one or two appointments. Souza et al. [24] found similar results, in 9 months follow-up, when performing pulpotomy in immature

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Table 3

<table>
<thead>
<tr>
<th>Risk factors</th>
<th>Non-adjusted model</th>
<th>Adjusted model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR</td>
<td>95% CI</td>
</tr>
<tr>
<td>Gender</td>
<td>1.29</td>
<td>(0.86–1.93)</td>
</tr>
<tr>
<td>Age at the pulpotomy</td>
<td>1</td>
<td>(0.98–1.01)</td>
</tr>
<tr>
<td>Number of appointments</td>
<td>0.55</td>
<td>(0.17–1.73)</td>
</tr>
<tr>
<td>Smoke</td>
<td>1.21</td>
<td>(0.78–1.87)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>0.59</td>
<td>(0.29–1.19)</td>
</tr>
<tr>
<td>Cardiopathy</td>
<td>0.38</td>
<td>(0.14–1.03)</td>
</tr>
<tr>
<td>Other systemic diseases</td>
<td>0.91</td>
<td>(0.51–1.64)</td>
</tr>
<tr>
<td>Denting bridge formation</td>
<td>0.14</td>
<td>(0.063–0.29)</td>
</tr>
</tbody>
</table>

Table 4

<table>
<thead>
<tr>
<th>Type of restoration</th>
<th>Non-adjusted model</th>
<th>Adjusted model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR</td>
<td>95% CI</td>
</tr>
<tr>
<td>Prosthetic crown</td>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td>Amalgam</td>
<td>1.78</td>
<td>(0.94–3.33)</td>
</tr>
<tr>
<td>Resin composite</td>
<td>5.46</td>
<td>(2.99–9.72)</td>
</tr>
</tbody>
</table>
permanent teeth with one or two appointments, also using calcium hydroxide as pulp capping material. These facts reinforce the notion that the correct diagnosis of pulp condition and vitality and the case preparation to avoid pulp contamination during the procedure are more important than the number of appointments for pulpotomy technique, or the age or gender of the patients.

Systematic reviews and meta-analysis on pulpotomy [8,17,25] have pointed to the difficulty in finding clinical indicators for follow-up of such techniques. They also mentioned that the existing clinical tests have produced several false negative results, and for this reason radiographic follow-up is essential for pulpotomy techniques. Thus, it is extremely important to have tangible radiographic indicator of pulpotomy success, and the presence of dentin bridge (Fig. 7) in the follow-up radiographs seems to be a protective factor (HR = 0.16; p < 0.001) and therefore a strong indicator of success. It is important to point out that the best radiographic techniques to detect dentin bridge formations are bitewing radiographic technique or long cone paralleling technique for periapical radiographs.

Several pulpotomy survival analysis studies, including systematic reviews [19] and other clinical studies [21,26,27], have also approached the importance of the final restoration on the success rates of pulpotomy techniques and concluded that an excellent crown setting is one of the keys for long-term success in these procedures. The present research has shown that prosthetic crown was the best choice of restoration for pulpotomized teeth, followed by amalgam restoration. Direct resin composite restorations are associated with higher failure rate of pulpotomy technique. Due to the fragility of the tooth structure after pulpotomy, fracture occurrence was also analyzed among different restorations, and the previous conclusion stands: prosthetic crown was the best choice (HR = 1.0, reference category) follow by amalgam (HR = 5.0) and resin composite (HR = 7.8).

5. Conclusions

The case selection, the correct diagnosis of pulp conditions, aseptic induction during the procedure, the use of dentin bridge inducing pulp capping materials, the selection of adequate lining restoration, and the optimal crown setting throughout prosthetic crown are the keys for pulpotomy success.

The absence of clinical symptoms and periapical alterations, followed by dentin bridge formation and final restoration with a hermetic prosthetic crown, are reliable indicators of long-term pulpotomy success.

The results of the present study help to establish the pulpotomy technique for permanent teeth as a treatment that is considerably simple, accessible, definitive and safe for all ages. Those characteristics turn pulpotomy into an excellent, cost-effective choice of vital pulp treatment for all populations.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jdent.2015.06.010.

References


