The vital amputation (VA) of deciduous teeth with the goal of maintaining their functionality for a limited period is a widely accepted measure. Vital amputation of permanents, however, is only approved for limited indications. While therapeutic agents such as calcium hydroxide (Ca(OH)2) and mineral trioxide aggregate (MTA) are recommended for VAs, formaldehyde (CH₂O) containing agents are a controversial subject.

The European Society of Endodontology (ESE) defines pulp amputation as a procedure during which part of the exposed vital pulp tissue is removed with the aim of maintaining vitality and function of the remaining parts of the pulp. The ESE recognises the following indications for VAs:

1. treatment of deciduous teeth
2. treatment of permanents with incomplete root growth
3. emergency measure

Indications 2 and 3 include the option of a later definitive root-canal treatment (RCT). Sidler recommends VA for the accidentally opened pulp of young molars and extremely curved, narrow root canals. Stern considers difficulty in opening the mouth an indication for VAs as well. McDougal et al. extend the indication for pulpotomy when there are economic concerns, as some patients are unable or unwilling to bear the cost of definitive treatment.
Your greatest resource is your time…
...what are you waiting for?

2007 Single File RCT’s
Concise & Precise TF Protocol

For detailed protocol / demonstration please contact:
North: Mohammed Naeem
Mobile: 07815 7816 25  Email: Mohammed.Naeem@sybrondental.com

South: Petra Helgesen
Mobile: 07977 1200 31  Email: Petra.Helgesen@sybrondental.com

SybronEndo
Sybron Dental Specialties
the expense of a RCT. According to Swift et al., a successful VA may be expected following traumatic or mechanical carious pulp exposure. We consider predictable success with the following prerequisites:

- Non-inflamed pulp
- Bacteria-proof closure
- Use of a pulp-compatible capping material

Seidler states the following regarding the success of VA:

- A higher rate of success is observed in cases of iatrogenic pulp exposure
- Treatment success is reduced in cases of complete root growth
- Molars are more successfully treated than incisors

For a pulpotomy with Ca(OH)2, Jensen presupposes that there is no pain existent anamnestically. Teixeira et al. corroborate the significance of pain prior to VA. In their study of 41 Ca(OH)2 vitally amputated permanent teeth, anamnestic pain existed in 12 cases. The pulpotomy of these aching teeth led to failure after six to eight months in 50 per cent of the cases (n = 6), while all other vitally amputated teeth were considered successfully treated. McDougal et al. report on 73 eugenol pulpotomies on aching permanent molars and premolars. A clinical success rate of 90 per cent after six months and 78 per cent after 12 months was observed. The teeth, which were free of pain at check-up, were radiologically controlled and it was shown that 49 per cent of the teeth were free of pathological findings after six months and 42 per cent after 12 months.

According to Jensen, pulpotomy is an attempt to stimulate hard tissue healing at the area of amputation. Fountain and Camp point out that a pulpotomy may result in canal calcification, internal resorption or necrosis of the pulp. Kozlow and Massler refer to literature that reports the formation of a dentine bridge in rat teeth under non-calcium-containing materials, such as wax, amalgam, acrylic resin and zinc oxide eugenol. In human teeth, the bridging under Ca(OH)2 was successful in 43 per cent of the cases and under antibiotics in 23 per cent of the cases. During their own tests on rat teeth, the authors assessed good reparative reactions with complete bridging following pulpotomy with Ca(OH)2, zinc oxide eugenol, cortisone and silver amalgam.

According to Alacam, various materials are recommended for pulpotomy: Ca(OH)2, formocresol, glutaraldehyde, ferrous sulphate, zinc oxide eugenol and polycarboxylate cement. Salako et al. compared MTA, formocresol, ferrous sulphate and bio-active glass with regard to their pulpotomy compatibility and found MTA to be the ideal pulpotomy agent.

Agents that contain CH2O and Ca(OH)2 are historically established VA agents for deciduous and permanent teeth. Massler et al. report a clinical success rate of 92 per cent following VA with Ca(OH)2. Taking postoperative X-rays into account, the success rate was reduced to 75 per cent after one year and dropped to 65 per cent after two to five years. The authors suggest several reasons for this failure:

- Pulp already heavily inflamed initially
- Too much pressure applied during application
- Disposal of the blood coagulum via haemostatic agents

Mejàre and Cvek performed partial pulpotomies using Ca(OH)2 on 37 permanent teeth (35 molars, two premolars). The patients were six to 15 years old and their pulpotomy had to be performed at least two years prior to inclusion in the study. Check-ups were performed at an average of 56 months (24 to 140). The teeth were separated into two groups (Table I). Two failures occurred in the first group, in teeth with incomplete root growth (after ten days and 48 months). The other 29 teeth (93.5 per cent) were treated successfully. In the second group, two failures occurred (after 10 and 24 months).

| Table I |
|-----------------|-----------------|
| 1st group (31 teeth) | 2nd group (6 teeth) |
| (no pathological findings radiographically, no anamnestic pain) | 3 with periodontal gap enlargement |
| 17 teeth with complete root growth | 2 of them with pain |
| 14 teeth with incomplete root growth | 3 with apical ostitis |
| 5 teeth with complete root growth | 1 tooth with incomplete root growth |
| 1 tooth with incomplete root growth |  |
The only control system offering the pre-programmed clinical sequences of the main implant brands is now available with a dedicated application for touchscreen tablets.

Discover the perfect working balance between your iPad* and exceptional electronics for controlling the MX-i LED micromotor. The most powerful motor on the market, with LED lighting guaranteeing a very long service life, is now also equipped with ceramic ball bearings that are lubricated for life.

The 20:1 L Micro-Series contra-angle and the new iChiropro system redefine ergonomics and ease of use.

* Compatible with iPad and iPad 2
in teeth with periodontal gap enlargement (one tooth with complete root growth and the other with incomplete root growth).

Molven states that there were no pathological findings in 1,391 root-filled roots in 51.6 per cent of the cases and in 236 pulpotomized roots in 65 per cent of the cases. Asgary and Eghbal report the successful use of a new VA agent called CEM, a cement mixture enriched with Ca, in 205 pulpotomies on molars. For comparison, 202 molars were extirpated vitally. The root-canal filling (RCF) was performed via lateral condensation with AH Plus (DENTSPLY DeTrey) as sealant. After seven days, 38 per cent of the pulpotomy treated and 60 per cent of the root-canal-treated patients reported needing analgesics. After six months, 88.94 per cent of the patients underwent a radiological check-up. The pulpotomy patients revealed a significantly higher success rate (p < 0.001).

The most frequently used VA agent for deciduous teeth is formocresol, a mix of CH2O, cresol, glycerine and water. A survey showed that formocresol pulpotomies on deciduous teeth were performed by general dentists in 73 per cent of the cases and by paediatric dentists in 98.2 per cent of the cases. The frequency of use on permanent teeth was lower: 18.9 per cent for general and 55.4 per cent for paediatric dentists.

Fisch published the results of pulp amputations of 600 teeth, which were performed with the CH2O-containing preparation Triopaste. Check-ups were done between six months and 18 years after amputation. Examination of the X-ray controls revealed a pathological apex in nine per cent. Eleven teeth were histologically examined. Hard substance formation was observed in the form of apical foramen closures and apposition at the lateral canal walls, which partially led to obliteration of the canal lumen.

During an accelerated test lasting up to 2.5 months, Overdiek tested N2 as CH2O-containing VA agent on human teeth. He observed that for several weeks following N2 application there was a possibility of a hard substance barrier forming. Over a period of 12 years, Stern carried out 175 N2 pulpotomies under relative isolation on teeth with complete root growth, regardless of possible anamnestic pain. Fifteen per cent of the patients experienced increased pain after treatment, which subsided within 48 hours. Four patients, however, developed pulpitis, which re-
sulted in the extraction of three teeth and conservative RCT of one tooth. Stern was able to track the outcome of 35 vitally amputated teeth over a longer period. During the course of check-ups, two teeth were extracted, one of them due to a fracture. Five years after treatment, Stern observed advancing calcification of the nerve channels.

Frankl considers the advantage of pulpotomy compared with RCT as there being no instrument fractures or perforations during pulpotomy. A possible failure could always be countered with a RCT. He asserts that Ca(OH)₂ pulpotomies can be successful only if teeth are asymptomatic prior to treatment and for accidentally opened pulp and, therefore, bleeding from the pulp.

According to the literature, N₂ VA on deciduous teeth renders significantly better results than Ca(OH)₂ pulpotomy. Therefore, Frankl performed N₂ pulpotomies on permanents as well. He selected only asymptomatic teeth whose pulp had been accidently exposed for treatment. The treatment was performed under a rubber dam and thus pulp bleeding did not have any effect. Two hundred and fifty cases were re-examined for up to 13 years. The age of the patients ranged between 22 and 55 years. Failures manifested by pain within 48 hours amounted to two per cent. The aim of the following study was to analyse the success and failure rates of N₂ VAs on permanent molars, and to compare these rates with vital molar extirpations done within the same period.

Material and method

The study was conducted in my dental practice, which is located in a rural area. Between 1992 and 1998, 795 VAs and 945 vital extirpations (VEs) were performed on molars. After treatment, 85 VA and 93 VE patients did not return to the practice and were thus excluded from the study, leaving 710 VAs and 852 VEs for analysis. During the treatment period, only N₂, which was approved by the district president of Düsseldorf, Germany, on 8 February 1990, was used as therapeutic agent (see Table II for composition).

The root canals were prepared according to the N₂ method: relative isolation, no root-canal rinsing and root-canal preparation with reamers only. For the RCF, N₂ mixed to a creamy consistency was applied with a lentulo spiral. The VA cavities were prepared 1 to 2 mm into the canals. N₂ mixed to a paste was inserted into the cavity with a filling instrument and lightly pressed with cotton. Minor bleeding was irrelevant.

In cases of heavier bleeding, the inserted N₂ was removed after a few minutes and then replaced with freshly mixed N₂. A synthetic closure of the cavity performed within the same sitting required a lining, which is not necessary for an amalgam closure. X-ray controls were later viewed at double and sevenfold magnification. The apical condition was differentiated as follows: apically without pathological findings, apically uncertain and apically pathological. The root with the worst apical findings was evaluated. This was also applicable for the classification of RCF levels.

Failures without accompanying X-rays were termed Mi1 and failures with accompanying X-rays were termed Mi2. The total failure percentage was not determined by simply adding Mi1 and Mi2, but by adding the number of Mi1s to the number of X-rays taken. The percentage of

<table>
<thead>
<tr>
<th>Tooth</th>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IVa</th>
<th>IVb</th>
<th>IVc</th>
<th>V</th>
<th>VI</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/26</td>
<td>269</td>
<td>241</td>
<td>89.6</td>
<td>42</td>
<td>17.4</td>
<td>142</td>
<td>58.9</td>
<td>3</td>
<td>22</td>
</tr>
<tr>
<td>17/27</td>
<td>168</td>
<td>152</td>
<td>90.5</td>
<td>25</td>
<td>16.4</td>
<td>88</td>
<td>58.6</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>18/28</td>
<td>5</td>
<td>5</td>
<td>100</td>
<td>1</td>
<td>20.0</td>
<td>2</td>
<td>40.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>36/46</td>
<td>274</td>
<td>249</td>
<td>90.9</td>
<td>24</td>
<td>9.6</td>
<td>148</td>
<td>59.4</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>37/47</td>
<td>201</td>
<td>177</td>
<td>88.1</td>
<td>25</td>
<td>14.1</td>
<td>97</td>
<td>54.8</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>38/48</td>
<td>28</td>
<td>28</td>
<td>100</td>
<td>6</td>
<td>21.4</td>
<td>16</td>
<td>64.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>945</td>
<td>852</td>
<td>90.2</td>
<td>123</td>
<td>14.4</td>
<td>295</td>
<td>58.2</td>
<td>14</td>
<td>63</td>
<td></td>
</tr>
</tbody>
</table>

Table III: Summarised VE results
failures was then determined from this sum. The statistical analysis was performed using SPSS (version 18).

Results

Of the VA patients 47.6 per cent were male and of the VE patients 52.4 per cent were male. The practice owner treated 70.1 per cent (n= 498) of the VA patients and 49.1 per cent (n= 418) of the VE patients and all the rest were treated by an assistant. The average age of VA patients was 34.6 years and that of VE patients was 30.6 years. The average observation period was 53.8 months (max. 165) for VAs and 49.4 months (max. 169) for VEs. Of the 710 VA cases 504 (71 per cent) and of the 852 VE cases 496 (58.1 per cent) were subject to follow-up X-ray controls.

A total of 61 VA and 77 VE failures were registered and classified as without accompanying X-ray (Mi1) or with accompanying X-ray (Mi2). Fifty-one of the 61 VA failures were followed-up with X-rays. Not all of the accompanying X-rays of the Mi2 failures revealed a failure.

Two VA failure X-rays and ten VE failure X-rays were wrongly evaluated as negative. Ten VA Mi1 cases were removed because of pain, three of them within a few hours after VA.

In two cases, a granuloma at an extracted root was indicated in the patient files. In two additional cases, the extraction followed after six and 11 days. In 12 of the 16 VE cases, extractions were performed because of pain (one day to 21 months after VE). Patients who visited the practice after pulpotomy made positive a negative reference to anamnestic symptomatic pain 241 times and 157 times, respectively. Subsequently, the failure rate was 10.8 per cent (n= 26) in the first case and 7.0 per cent (n = 11) in the latter case. The difference was insignificant statistically (p = 0.114).

The failure diagnosis after VA was most frequently made for the lower second molar (18.5 per cent) and after VE for the lower first molar (19 per cent). The lower wisdom teeth were conspicuous because the failure rate was only 4.7 per cent after VA, and no failure at all was observed after VE. Not every failure diagnosis led to therapeutic consequences such as extractions.

Altogether, 206 (28.6 per cent) VA and 123 (14.4 per cent) VE teeth were extracted during the follow-up phase (very statistically significant difference; p = 0.000). The largest number of extractions, namely 51.9 per cent (n= 107) of the VAs and 46.3 per cent (n= 57) of the VEs, were performed because the teeth had been destroyed or fractured. The lower wisdom teeth were the most frequently affected in the case of pulpotomy (61.8 per cent; n = 21) and the upper second molars in the case of VE (64 per cent; n = 16).

A failure was decisive for the removal of 23.3 per cent (n = 48) of the extracted VA teeth and 36.6 per cent (n = 45) of the extracted VE teeth. Most frequently extracted due to failure were the vitally amputated upper second molars (34.8 per cent; n = 8), and the vitally extirpated lower second molars (54.2 per cent; n = 13). The lower wisdom teeth (34 extractions (n = 3; 8.8 per cent) in the pulpotomy group) and the upper second molars (42 extractions (n = 13; 31 per cent) in the VE group) were extracted least often. The VE and VA results are shown in Tables III and IV.
BDTA DENTAL SHOWCASE 2012
4-6 October 2012, ExCeL London

A VOYAGE OF DISCOVERY

The UK’s largest dental exhibition
Discover what’s new
Gain technical & business advice
Experience hands-on demonstrations
Get ‘out of this world’ special offers

Register now for your free ticket:
ONLINE: www.dentalshowcase.com
HOTLINE: + 44 (0) 1494 729959
TEXT: your name, postal address, occupation, and GDC number to 07786 206276
EMAIL: ers@dentalshowcase.com

Scan the barcode with your phone to reserve your ticket for Showcase 2012

BDTA Dental Showcase 2012 is organised by The British Dental Trade Association,
Mineral Lane, Chesham, Bucks, HP5 1NL  Tel: 01494 782873  e-mail: admin@bdta.org.uk

4-6 October 2012 ExCeL London
Furthermore, the question of whether the RCF level following VE had any significance with regard to the failure rate was pursued. The RCF levels were divided into three levels. The total failures of these three groups were calculated as described under material and method (Table V). Without considering the indication range, anamnestic symptoms, tooth position and RCF level, the total failure rate was 11.9 per cent for VAs and 15 per cent for VEs (statistically insignificant; p = 0.644). The VE failure rate of the RCF level of -4, -3 corresponded exactly to the VA failure rate of 11.9 per cent. There was no statistically significant difference (p = 0.226) in failure between RCF levels -4, -3 and -2, -1, 0. The RCF level of -5 showed significantly more failures compared with the RCF levels of -4, -3 (p = 0.020) and -2, -1, 0 (p = 0.002).

Discussion

A direct comparison between VAs and VEs, especially as regards incomplete root fillings, was only possible within limits, as the number of VAs consisted mainly of a negative selection, which otherwise would have been entrusted to the pliers. The twice as high extraction frequency of vitally amputated teeth compared with that of vitally extirpated teeth (28.6 per cent versus 14.4 per cent) may be attributed to the adverse baseline situation. Fractured or destroyed teeth were the reason for extraction for 51.9 per cent of all extractions in the case of VAs. For VEs, this rate was 46.3 per cent. However, the extraction reason "endodontic failure" was attributed in 36.6 per cent of the extractions to the VA teeth and in 23.3 per cent of the VE teeth.

Anamnestic pain causing an increased frequency of failure in VA cases, which was also observed by Teixeira et al. following Ca(OH)$_2$ treatment, was statistically insignificant. Stern and Frankl also point out increased pain following VA. This was observable during our study as well. Nevertheless, the total failure rate for vitally amputated teeth was lower (11.9 per cent) than the average rate of 15.1 per cent for vitally extirpated teeth.

The evaluation of pulpotomy cases only with accompanying X-rays revealed a failure rate of 10.1 per cent, which is comparable to the nine per cent Fisch encountered with the Triopaste. Frankl reports only two per cent of failures af-
After N2 VA, although he had done stringent case selection. In contrast, the radiological-pathological findings concerning eugenol pulpotomies in pain-free teeth amounted to 58 per cent after 12 months. Fifty per cent of all Ca(OH)2 pulpotomies of aching teeth resulted in failure after six to eight months. Massler et al. observed a total failure of 65 per cent, two to five years after Ca(OH)2 VAs.

The correlation between failure and RCF level following VEs was investigated. Adequately filled teeth (-2, -1 apicem) showed a failure rate of 8.9 per cent, heavily underfilled teeth a rate of 22.1 per cent. Hence, the conclusion may be drawn that the success rate of VAs corresponds to the one of properly performed root fillings following VEs, and is far superior to a noticeably underfilled root filling. Molven attributes a more favourable peri-apical situation to pulpotomized than to root-filled roots.

In their study, Asgary and Eghbal do not explain the technical performance of the RCF. However, they establish that pulpotomies are statistically significantly superior to RCTs of vital molars, although radiological failure is neither defined nor numerically expressed. Additionally, the follow-up time of six months is considered very brief.

Summary

A comparison of 710 N2 VAs and 852 N2 root-filled molars after VE was done. The average follow-up period was 53.8 months for VAs and 49.4 for VEs. The total failure rate (radiological and clinical) was 11.9 per cent following VAs, which is equivalent to that of VEs with slight underfilling (RCF level -4, -3). Adequately filled root canals led to fewer failures (8.9 per cent) than VAs. With a failure rate of approximately 19 per cent, the lower first VE- and second VA-molars were most frequently affected.

During the follow-up period, 28.6 per cent of all VA and 14.4 per cent of VE teeth were extracted. Fractured or destroyed teeth were the reason for extraction in 51.9 per cent of all VA and in 46.3 per cent of all VE cases. The extraction reason “endodontic failure” occurred less frequently after VA (23.3 per cent) than VE (36.6 per cent).

For the practice

The patient should be advised of possible pain following the subsiding anaesthetic effect. Analgesics are indicated after VA. An N2 VA is more successful than an insufficient root filling after VE. Vital amputation is indicated in cases of almost inaccessible canal systems, open apical foramina and for economic reasons.

Instead of an extraction or the impossibility of a VE with adequate root filling, it is possible to consider— besides a full pulpotomy, which was the subject of the present study—a partial pulpotomy on:

- upper molars: VA of the buccal canals, filling of the palatal root
- lower molars: VA of the mesial canals, filling of the distal root
- deep crown margin caries, partial removal of the pulp cavum

Editorial note: A complete list of references is available from the publisher.