Factors influencing the long-term results of endodontic treatment: a review of the literature

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The purpose of this review of the literature is to examine the factors and their influence on the outcome of endodontic treatments, and also to attempt to have an authors' consensus concerning the impact of these factors on long-term results. The documentary research was conducted using the meta-analysis principles of critical reading of the literature. Two groups of factors can be identified regarding the outcome of endodontic treatments: those which influence the success of the procedure and those which do not significantly affect the success rate. Agreement is obtained in all studies on two major factors, the preoperative periapical status and the apical limit of the obturation, which appear to strongly influence the success of endodontic therapy. This review highlights the methodological problems of retrospective studies and points out the need for consensus regarding the evaluation criteria of root canal therapy.

Key words: Endodontic treatment, evaluation, meta-analysis, periapical disease, root canal therapy, treatment outcome

The principles of endodontic therapy have been described almost 50 years ago, and led to the standardisation of endodontic materials. This, in turn, has prompted several technical modifications which resulted in a significant improvement in the clinical results. The review of the endodontic literature published in the past twenty years shows many in vitro studies designed for product testing of the materials used in endodontics. Indeed, very few studies are dedicated to clinical evaluations and long-term assessments of endodontic treatments. The first scientific evaluation of endodontic treatments underscored the determination of criteria which have been used in most subsequent surveys.

The aim of this paper was to delineate the factors which may be taken into account in a consensus about endodontic therapy. A review of the currently available literature is presented including the factors influencing the outcome of endodontic treatments. Moreover, a consensus of authors' findings regarding the impact of these factors on long-term results of endodontic treatments is proposed.

Materials and methods
The documentary research was led...
using the MEDLINE data-base from January 1982 to January 2001 based on the following key-words: ‘root canal therapy / treatment outcome’ and ‘endodontic / evaluation studies’. A total of 51 papers was retrieved with these key-words, from which secondary research identified 29 additional references. These 80 papers were then analysed using the meta-analysis principles of critical reading of the literature. The following exclusion criteria were applied if:

* the follow-up period or methodology were not mentioned
* the material included a number of teeth less than 200
* the study was poorly led or gave success or failure rates without studying the factors influencing them
* endodontic retreatments were considered in the study.

Using these criteria, ten trials were considered for further analysis; two of them were reported in two parts, therefore twelve publications were analysed (Table 1).

### Results

All the studies were retrospective with an observation period ranging from one to twenty years. Overall, the success rate of the root canal therapy was comprised between 53 per cent to 94.5 per cent with an average rate of 83.2 per cent. The failure rate was between 5 per cent and 34 per cent of the cases.

Regarding the outcome of endodontic treatments, fifteen factors appeared of interest to study. Two groups of factors could be delineated. Those which influence the success of the procedure and those which do not significantly affect the success rate (Table 2).

### Factors which appear to affect significantly the treatment outcome

Agreement was found in all studies on two major factors – the preoperative periapical status (PAS) and the apical limit of the obturation (ALO). All authors agreed that the PAS with regard to the biologic factors is of a paramount importance for the outcome of treatments. The presence of pre-existing periapical lesions appeared to reduce the endodontic success rate from 8 per cent to 23 per cent.

With regard to the apical level of the root filling, all authors except Morse agreed that the rate of failure is more important

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### Table 1 Main features presented in each of the reviewed papers

<table>
<thead>
<tr>
<th>Authors</th>
<th>Operators</th>
<th>Number of teeth</th>
<th>Follow-up (years)</th>
<th>Success</th>
<th>Failure</th>
<th>Doubt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adenubi et al., 1976</td>
<td>Hospital staff</td>
<td>870</td>
<td>5-7</td>
<td>88.20%</td>
<td>7.00%</td>
<td>4.80%</td>
</tr>
<tr>
<td>Jokinen et al., 1978</td>
<td>Students</td>
<td>1782</td>
<td>2-7</td>
<td>53.00%</td>
<td>34.00%</td>
<td>13.00%</td>
</tr>
<tr>
<td>Kerekes and Tronstad, 1979</td>
<td>Students</td>
<td>478</td>
<td>3-5</td>
<td>91.00%</td>
<td>5.00%</td>
<td>4.00%</td>
</tr>
<tr>
<td>Barbakow et al., 1980</td>
<td>General dentist</td>
<td>332</td>
<td>1-9</td>
<td>87.40%</td>
<td>6.90%</td>
<td>5.70%</td>
</tr>
<tr>
<td>Nelson 1982</td>
<td>General dentist</td>
<td>299</td>
<td>&gt; 2</td>
<td>81.90%</td>
<td>18.10%</td>
<td></td>
</tr>
<tr>
<td>Swartz et al., 1983</td>
<td>Students</td>
<td>1007</td>
<td>20</td>
<td>87.79%</td>
<td>12.21%</td>
<td></td>
</tr>
<tr>
<td>Morse et al., 1983</td>
<td>Authors</td>
<td>220</td>
<td>1-3</td>
<td>94.50%</td>
<td>5.50%</td>
<td></td>
</tr>
<tr>
<td>Besse and Woda, 1985</td>
<td>Students</td>
<td>231</td>
<td>1</td>
<td>73.23%</td>
<td>16.48%</td>
<td>10.29%</td>
</tr>
<tr>
<td>Sjögren et al., 1990</td>
<td>Students</td>
<td>849</td>
<td>8-10</td>
<td>91.00%</td>
<td>9.00%</td>
<td></td>
</tr>
<tr>
<td>Smith et al., 1993</td>
<td>Endodontists</td>
<td>821</td>
<td>5</td>
<td>84.30%</td>
<td>15.70%</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2 Factors with or without influence on the outcome of endodontic treatment

<table>
<thead>
<tr>
<th>Factors studied</th>
<th>Numbers of studies studying the factors</th>
<th>The factor has an influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-operative periapical status</td>
<td>10</td>
<td>Yes 0</td>
</tr>
<tr>
<td>Periapical limit of the obturation</td>
<td>10</td>
<td>Yes 0</td>
</tr>
<tr>
<td>Obturation quality</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Pulpal pre-operative diagnosis</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Presence of apical foramen during the treatment</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Observation period</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Root filling technique</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Type of filling material</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Type of treated tooth</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Gender</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Age</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Number of treatment sessions</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Type of intra canal irrigation</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Presence of complications during the treatment</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

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when an over-extension of the filling goes beyond the apical foramen. Extruded materials may have an irritating effect on the periapical tissues. Over-filling is often preceded by an over-instrumentation, which may push pulp remnants and micro-organisms beyond the apex.

Additional factors were also examined: the observation period, the tooth restoration following treatment, the penetration of the apical foramen during the procedure, the radiographic density of the filling material and the pulpal preoperative diagnosis.

The follow-up period affects the success rate, any bony change, be it failure or healing, cannot be visualised for several months on a radiograph and therefore a minimum observation time of six months is needed to demonstrate any change in periapical healing. Results obtained with observation periods shorter than one year are unacceptable since the vast majority of unsuccessful cases were noticed within two years of treatment.

According to Jokinen and Swartz, the lack of an hermetic coronal restoration over endodontically treated teeth increases the rate of failure in the long run.

The penetration of the apical foramen during the procedure due to over-instrumentation influences the failure rate, particularly in teeth with preexisting apical lesions.

With respect to the radiographic density of the filling material, although non-ascertainable on radiographs the homogeneity of the filling material and the absence of voids are likely to be important.

At least, the pulpal preoperative diagnosis (vital pulp versus necrotic pulp) appears a controversial item. It is noted with no influence in seven reports while a significant effect is found in five others. No appropriate explanations are offered by the authors regarding this criterion. As expected, the diagnosis of a vital pulp and an adequate apical limit of the obturation, allows a better success rate.

Factors which would not affect the treatment outcome significantly:

The gender of the patient has no influence on the results. Swartz reported a higher success rate of 90.3 per cent for women (as opposed to 84.7 per cent in men), while Smith reports a better rate of 6 per cent for men (87.5 per cent) compared with a 81.5 per cent rate for women. No explanation is suggested for these conflicting results.

Concerning tooth type, Kerekes and Barbakov found a lower success rate for mandibular molars, but all other authors except Besse did not demonstrate significant differences between teeth.

No difference was demonstrated when comparing the gutta percha technique to the lateral condensation technique. However, when comparing the gutta percha technique to the silver cone technique, the success rate of the former increased.

Other treatment parameters such as the number of treatment sessions, the type of intra-canal irrigation, the presence of complications during the treatment were not shown to influence the final outcome.

Discussion

In reviewing these data, the variability of the reported observations appears as a source of complexity with regard to the evaluation of endodontic practices. In a comprehensive review of previously published literature in 1990, Stabholz outlined the discrepancy of the success rate of endodontic treatments; the major causes of this variability were related to the design of the studies and to the evaluation criteria.

The existence of interpretation bias

From a methodological standpoint, the population samples were not randomly selected and retrospectively studied in all reviewed studies. The assessment of endodontic treatments was mainly based on the observation of clinical radiographs. Eckerdorn and Magnusson emphasised the risks of misinterpreting dental radiographs. When the examiners estimate the quality of the seal, major variations are noted because of the presence of surrounding tissues, particularly for the posterior teeth. Moreover, the reliability of radiographic evaluation must be taken into account; also, the radiographic image of a periapical rarefaction is modified according to the angulation of the film and adjacent anatomic structures (maxillary sinus, chin foramen) are other sources of misinterpretation.

The examiner can be a source of variability. In 1972 Goldman showed that when six examiners looked at the same root canal radiographs they agreed, without confering, on 50 per cent of the radiographs; in addition when observing the same radiograph at two different times, each examiner can express a different interpretation. In order to overcome the inter and intra-observer validity, a protocol has been suggested by Goldman in which radiographs have to be examined by two independent observers. In the case of disagreement, they have to confer with each other and reach a consensus; if no consensus is achieved, a third opinion is sought. Using this procedure, the disagreement rate drops from 50 per cent to 25 per cent. This protocol has been used in the twelve studies reviewed in the present work. Interpretation of the post-treatment radiograph is to-date the most
The radiographic criteria for judgement of the treatment were delineated by Strindberg\textsuperscript{2} as follows:

A success when:
- the contours, width and structure of the periodontal margin are normal
- the periodontal contours are widened mainly around the excess filling.

A failure when there is:
- a decrease in the periradicular rarefaction
- an unchanged periradicular rarefaction
- an appearance of new rarefaction or an increase of the initial lesion.

Uncertain when:
- there are ambiguous or technically unsatisfactory control radiographs which could not be repeated for any reason
- the tooth is extracted prior to the 3-year follow up owing to an unsuccessful treatment of another root of the tooth.

Clinical criteria were suggested by Bender\textsuperscript{22}. Cases are considered successful when there is:
- an absence of pain or swelling
- a disappearance of any sinus tracts
- radiographic evidence of resolved or arrested areas of rarefaction after a post treatment interval of 6 to 24 months
- no loss of function.

The following criteria are used to determine failures:
- presence of pain, swelling, or sinus tracts
- loss of function
- increasing size of bone rarefaction or persistence of the bone lesion following treatment
- development of bone lesion not originally present.

All studies\textsuperscript{4-15} combined radiographic and clinical criteria as described by Strindberg\textsuperscript{2} and Bender\textsuperscript{22} and led to different conclusions. According to Morse\textsuperscript{11,12}, a simple reduction of the periapical radiolucent area can be considered as a success; thus, he found the highest success rate at 94.5 per cent. Conversely, according to Jokinen\textsuperscript{5}, the treatment is successful if the size of the periapical area reduces, if the tooth has a definitive coronal restoration re-establishing its function and if the bone repair appears complete (with continuity of the lamina dura); accordingly, he reported the lowest success rate at 53 per cent.

This variability enhances the need for a consensus of authors in order to validate these results. In 1994, the European Society of Endodontology and the British Endodontic Society\textsuperscript{23} presented new quality guidelines for endodontic treatments with the purpose of delineating current good practices covering all aspects of endodontology; these guidelines emphasised the following items:
- determination of the working length – which should be within 0.5 and 2mm of the radiographical image of the root apex
- preparation of the root canal system
- obturation of the root canal system
  - the prepared root canal should be entirely filled
  - no voids should be noted along the root canal filling material and the canal walls
- no canal space should be visible beyond the end-point of the root canal filling.

Despite this consensus report, Dummer\textsuperscript{24} outlined that the overall quality of root fillings as completed by general practitioners, does not always fulfill these quality standards; for the long-term prognosis, the quality of root canal treatment has significant impact on the maintenance of the tooth.

Concerning the long-term prognosis of endodontically treated teeth, the presence of periapical disease is five to ten times higher for endodontically treated teeth than for vital teeth\textsuperscript{25-33}, while the periodontal prognosis is more favourable for vital teeth than for endodontically treated teeth\textsuperscript{34-36}. Moreover, using randomly selected samples, prevalence studies\textsuperscript{25,26,28,29,37} demonstrated that inadequate canal obturation or excess of root filling material, beyond the apex, were significantly related to periapical lesions. In addition, the presence of periapical lesions tends to lower the long-term prognosis of the endodontically treated tooth. Sjögren\textsuperscript{38}, in 1997, showed a 26 per cent lower success rate for teeth that were infected at the time of obturation.

In a prospective study, Byström\textsuperscript{39} followed up the healing of seventy nine treated teeth with pre-existing periapical lesions from two to five years and he found a significant correlation between the size of the lesions and the number of bacteria cells present in the root canal system. Since anaerobic bacteria have the ability to establish themselves and survive in the periapical tissue outside the root canals, teeth with pre-operative periapical areas, however well prepared and sealed may still fail because of their presence.

Buckley\textsuperscript{33} showed that adequate radiographic root filling images are still associated with periapical disease in more than 14 per cent of the cases and 'the only true reason for failure of endodontic treatment
is the persistence or introduction of microbes, and their by-products into the root canal system and periapical tissue regions.

Lin²⁶ studied two hundred and thirty-six cases of endodontic failures using biopsies taken during endodontic surgery. When the pre-operative periradicular status was correlated with the histobacterial findings, stainable bacteria were present in a significantly higher percentage in the teeth associated with pre-operative periradicular rarefaction (80 per cent) than without (20 per cent).

In a recent study, Sundqvist⁴¹ revealed that the main cause of root canal treatment failures was microorganisms persisting in the apical parts of root canals of root-filled teeth. The nature of the infection in previously treated cases markedly differs from that in untreated cases and, at the time of root filling, has a negative influence on the overall prognosis. He demonstrated that the outcome of endodontic treatment also correlates with the size of the periapical lesions before retreatment; teeth with larger lesions have a poorer prognosis than teeth with smaller lesions.

Moreover, a recent review by Siqueira⁴⁵ concluded that failures can occur despite the highest standards used to perform root canal treatment. Even in well-treated cases, the endodontic failure results from persistent or secondary infection rather than non microbial factors which were never formally demonstrated in the existing literature.

This review emphasises the difficulty in analysing long-term results of endodontic treatments and relating them to the causes of failure. Few evaluation studies have been conducted; the designs and methodologies are dissimilar, and this consequently makes comparisons difficult. In public health, these failures represent an important problem because they are numerous, costly, and induce potentially harmful infectious complications⁴³ such as focal infection, infective endocarditis and brain abscesses⁴⁴, which for a large part, can be avoided⁴⁶.

Because new materials, techniques and instruments are constantly entering the market-place⁴⁶, the evaluation of practices is becoming an important parameter in therapeautic activity. In the specific case of endodontic treatment, the evaluation must take into account the bacterial aetiology of endodontic infections, the specificity of the treatment and the importance of follow-up, upon which the validity of the treatment can be asserted.

References

23. European Society of Endodontontology. Consensus report of the ESE on quality guidelines for endodontic treat-