Abstract – The objective of this study was to determine the periapical status and the quality of root canal fillings and to estimate the endodontic treatment needs in a German population. Clinical and radiographic data and the operative procedures performed were evaluated on 323 patients coming to a dental surgery in Stuttgart, Germany, in 1993. In 182 individuals at least one tooth exhibited a root canal filling, a necrotic pulp or an irreversible pulpitis. Out of the 7897 teeth examined, 215 (2.7%) had a root canal treatment (category A), 122 being non-endodontically treated (1.5%) did not respond to the sensitivity test (category B) and 53 (0.7%) were diagnosed as having irreversible inflamed pulp tissue (category C). The prevalence of teeth associated with radiographic signs of periapical pathosis was 61% in the group of root canal filled teeth and 88% in the group of pulpless and non-endodontically treated teeth. Using the level and the density of the root canal filling as criteria for evaluating the technical standard, only 14% of the endodontic treatments of non-apicectomized teeth were qualified as adequate. The minimal endodontic treatment need is 2.3% related to all examined teeth when the root canal filled teeth with clinical symptoms of periapical periodontitis (category A) and those of categories B and C are included. The real endodontic treatment need is suggested to be larger when considering that the technical quality of the obturation is poor in most symptomless endodontically treated teeth associated with a periapical lesion. In the case of retreatment of these teeth, the endodontic treatment need would then be calculated at 3.7%.

Epidemiological data on the periapical status, the quality of root canal treatments and the endodontic treatment needs in Germany are scarce. Three studies (1–3) have been performed analysing selected patient groups of a University dental clinic. Attention was focused on the prevalence and the quality of root canal fillings by evaluation of intraoral or panoramic radiographs. In one paper only (2), an attempt was made to estimate radiographically the need for endodontic treatment in 200 individuals suffering from periodontal diseases. Clinical examinations, including sensitivity tests or the results of operative procedures which could probably reveal the need for additional root canal treatments, were not considered.

In Germany, the number of specialists focusing on clinical endodontics is negligible. The vast majority of patients seeking dental care or emergency treatment will primarily consult general dental practitioners. In
Weiger et al.

Table 1. Age distribution of the patient sample (n=323). Group I represents the patients having at least one tooth with an obturated root canal or one tooth associated with an irreversibly inflamed or necrotic pulp. This type of tooth is not present in the individuals of Group II

<table>
<thead>
<tr>
<th>Age group</th>
<th>Group I</th>
<th>Group II</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-19</td>
<td>6</td>
<td>15</td>
<td>21 (6.5%)</td>
</tr>
<tr>
<td>20-29</td>
<td>58</td>
<td>66</td>
<td>124 (38.4%)</td>
</tr>
<tr>
<td>30-39</td>
<td>51</td>
<td>36</td>
<td>87 (26.9%)</td>
</tr>
<tr>
<td>40-49</td>
<td>22</td>
<td>12</td>
<td>34 (10.5%)</td>
</tr>
<tr>
<td>50-59</td>
<td>22</td>
<td>6</td>
<td>28 (8.7%)</td>
</tr>
<tr>
<td>60-69</td>
<td>9</td>
<td>2</td>
<td>11 (3.4%)</td>
</tr>
<tr>
<td>70-79</td>
<td>12</td>
<td></td>
<td>16 (5.0%)</td>
</tr>
<tr>
<td>80-89</td>
<td>2</td>
<td></td>
<td>2 (0.6%)</td>
</tr>
<tr>
<td></td>
<td>182</td>
<td>141</td>
<td>323 (100.0%)</td>
</tr>
</tbody>
</table>

In contrast, patients of a dental clinic affiliated with a University are frequently referrals or have special dental problems, thus representing a highly selected material. This study was designed to determine retrospectively the periapical status and the quality of root canal fillings in individuals seeking examination/treatment in a selected German general dental surgery. Furthermore, an estimation of their endodontic treatment was done on the basis of clinical and radiographic data and of the operative procedures performed accordingly.

Material and methods

Patients who came to a general dental practice during the regular consultation hours for the first time or after a period of 5 years in 1993 were included in this study. Three full-time general dental practitioners examined and treated the patients in their private surgery situated in the centre of Stuttgart, a city with about 600,000 inhabitants in the southern part of Germany. Children less than 12 years old were not considered in this study. Out of the 323 subjects examined, 54% were females and 46% males. The average patient age was 35.2 years. The age distribution is illustrated in Table 1. The patients' records including intraoral and/or panoramic radiographs formed the basis for the study.

Clinical criteria

The recorded history of dental pain, if present, and the outcomes of the clinical examination were evaluated for each patient. The criteria listed in a special form included clinical symptoms indicating symptomatic pulpitis or an endodontically induced periapical periodontitis, tooth vitality, potential causes for pulpal involvement, type of coronal restoration and marginal seal of the restoration (Table 2). Third molars were excluded from the analysis.

Radiographic criteria

Periapical radiographs were available for most teeth which did not clearly respond to the sensitivity test. In some patients, panoramic radiographs had been taken for other reasons. All films were processed in a standardized automated machine. Radiographs which were not available or which did not allow a proper evaluation of any single criteria of interest due to technical shortcomings or overprojections of anatomical structures were separately registered.

A tooth with radiopaque material within the confines of the suggested root canal(s) was rated as "endodontically treated" tooth. Signs of periapical pathosis, the density of the root canal filling and its apical extension related to the radiographic apex and the presence of an intracanal post were recorded (Table 2). The widening of the periapical periodontal ligament space exceeding about two times the width of a normal lateral periodontal ligament space was assessed as "periapical radiolucency". Multi-rooted teeth were categorized according to the root with the most insufficient root canal filling and/or with the highest periapical score.

Radiographic interpretation

In the preliminary phase of the study, a prior calibration of two dentists (SH and GH) was carried out by an experienced endodontist (RW). Thirty-one radiographs showing teeth with obturated root canals...
or with signs of periapical pathology were used to discuss the criteria to be evaluated and the scoring of the variables. In the main part of the study, all radiographs were interpreted by the two examiners (SH and GH) using an illuminated viewing box. The examiner variability between SH and GH was determined by calculating kappa (κ) values for detecting a periapical radiolucency and for evaluating the density and the apical extension of the root canal filling. They were 0.95, 0.92 and 0.94, respectively, indicating a high inter-observer agreement for the selected variables. In the case of disagreement, the final decision was made by a third person (RW).

Treatment procedures

Operative procedures initiated during the first six months after initial clinical examination were additionally subjected to the analysis to get a more accurate basis for estimating the endodontic treatment needs. Treatment planning and the necessity of performing a particular treatment was based on the clinical and radiological findings. Consequently, the relief of tooth pain by eliminating the potential cause, the removal of deep carious lesions in asymptomatic teeth and the management of traumatized teeth were of first concern. This might support the initial diagnosis of irreversible pulpitis or necrotic pulp.

The examined teeth were integrated into four different categories which were defined as stated in Table 3. The distribution of the teeth according to the selected category and the type of radiograph is shown in Table 4.

Results

In 323 patients, 7987 teeth were investigated. Out of these subjects, 164 had at least one tooth integrated within the category A, B or C. Eighteen patients had exclusively one pulpless tooth of which the radiograph could not be properly evaluated or was not available (category D). Out of the examined teeth, 241 (3.0%) demonstrated a periapical radiolucency. A root canal filling was present in 215 (2.7%) teeth of which 61% were associated with a periapical lesion. Fifty-three teeth (0.7%) displayed signs of irreversible pulpitis.

Out of the 188 root canal filled teeth without periapical surgery, 72 showed no area of periapical pathosis radiographically (Table 5). The quality of the root canal filling was satisfactory only in 9 cases. In the remaining 116 root canal filled teeth without periapical surgery, a periapical lesion was present. The obturation of the root canals seemed to be adequate in 18 cases. A total of 27 teeth appeared to have had an apicectomy (Table 5). Only 12 surgically treated teeth elicited a homogenous root canal filling extending to the amputation level; 16 were associated with a periapical radiolucency. Furthermore, 11 out of the 215 endodontically treated teeth presented clinical signs of periapical periodontitis.

Teeth in the maxilla (n=151) were found to have obturated root canals more frequently than teeth in the mandible (n=64) (Table 5). Upper anterior teeth were associated with the highest incidence of being endodontically treated (n=72). Lower anterior teeth showed the lowest incidence (n=4).

The category B (Table 6) comprised 122 teeth (1.5%) including 51 cases showing clinical symptoms of periapical inflammation. Upper anterior teeth were predominantly encountered in this group (n=38). The vast majority (n=107) demonstrated radiographic signs of periapical pathology.

Fifty-three teeth (0.7%) (category C) responded to the sensitivity test, but had to be root canal treated mainly due to pulpal involvement as a result of deep carious lesions (Table 7). Forty-eight out of the 53 teeth were coupled with clinical symptoms as a result of irreversibly damaged pulp tissues. Molars were most frequently concerned (n=29). A widening of the periapical periodontal ligament space was detected in 30 cases.

The minimal endodontic treatment need is suggested to be 2.3% related to all examined teeth. Included are the root canal filled teeth with clinical symptoms of periapical periodontitis (category A) and those of categories B and C. The real endodontic treatment need is undoubtedly larger when considering that the technical quality of the obturation is poor in most symptomless endodontically treated teeth associated with a radiographically detectable periapical lesion. In the case of retreatment of these teeth, the
endodontic treatment need would then be calculated at approximately 3.7%.

**Discussion**

The study material consisting of patients from a general dental practice does not represent a random sample of the German population in the area of Stuttgart. However, it may provide useful data on the endodontic quality and the endodontic treatment needs in Germany compared to a highly selected patient population of a dental school clinic affiliated with a university. Such patient groups have served as a basis for more recent investigations (1–3) documenting the prevalence and the quality of endodontic treatment as well as the periapical status.

The present study was restricted to patients who came to the selected dental surgery for the first time or after a period of at least 5 years. The reasons why these subjects chose this practice have not been recorded. Of the 323 patients, women dominated slightly with 54%. The age distribution clearly showed that the younger individuals (12–39 years) made up 72% of the whole sample. The average number of remaining teeth per individual was 24 (third molars excluded). How far this figure is comparable with that of the whole German population could not be definitively assessed.

The patient's dental history, the clinical examination and the operative procedures supply important information about the presence of an irreversible pulpitis, the potential causes of pulpal exposure and the number of pulpless teeth without any radiological signs of periapical pathosis. However, a misdiagnosis made by one of the three practising dentists might not be completely excluded, possibly resulting in a false treatment or a non-treatment. Particularly the sensitivity test on teeth with full ceramic crowns or with radiographically obliterated root canals might yield misleading results. Undoubtedly, the true endodontic treatment need can be estimated more comprehensively when radiographic data are supplemented by clinical findings.

Periapical radiographs or orthopantomograms were used to evaluate the technical standard of root canal fillings and to detect periapical lesions. The presence or absence of periapical or lateral lesions was assessed instead of applying a more detailed periapical scoring system according to Ørstavik et al. (4). In this connection, the widening of the periodontal ligament space exceeding two times the width of the lateral periodontal ligament space was interpreted as

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**Table 5. Distribution of the teeth of category A according to tooth group, periapical radiolucency, density and length of the root canal filling and marginal seal of coronal restoration (u.: upper, l.: lower, ant.: anterior, apicect.: apicectomized, ext.: extruded)**

<table>
<thead>
<tr>
<th>Category A</th>
<th>n</th>
<th>Radiolucency</th>
<th>Density</th>
<th>Length</th>
<th>Marginal seal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>no</td>
<td>yes</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>u. ant. teeth</td>
<td>55</td>
<td>20</td>
<td>35</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>u. premolars</td>
<td>45</td>
<td>20</td>
<td>25</td>
<td>18</td>
<td>27</td>
</tr>
<tr>
<td>u. molars</td>
<td>28</td>
<td>12</td>
<td>16</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>l. ant. teeth</td>
<td>4</td>
<td>–</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>l. premolars</td>
<td>22</td>
<td>11</td>
<td>11</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>l. molars</td>
<td>34</td>
<td>9</td>
<td>25</td>
<td>10</td>
<td>24</td>
</tr>
<tr>
<td>subtotal</td>
<td>188</td>
<td>72</td>
<td>116</td>
<td>56</td>
<td>132</td>
</tr>
<tr>
<td>apicect. teeth</td>
<td>27</td>
<td>11</td>
<td>16</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>total</td>
<td>215</td>
<td>83</td>
<td>132</td>
<td>71</td>
<td>144</td>
</tr>
</tbody>
</table>

---

**Table 6. Distribution of the teeth of category B according to tooth group, periapical radiolucency and type of restoration (u.: upper, l.: lower, ant.: anterior)**

<table>
<thead>
<tr>
<th>Category B</th>
<th>n</th>
<th>Radiolucency</th>
<th>Restoration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>u. ant. teeth</td>
<td>38</td>
<td>6</td>
<td>32</td>
</tr>
<tr>
<td>u. premolars</td>
<td>13</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>u. molars</td>
<td>21</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>l. ant. teeth</td>
<td>9</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>l. premolars</td>
<td>21</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>l. molars</td>
<td>20</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>total</td>
<td>122</td>
<td>15</td>
<td>107</td>
</tr>
</tbody>
</table>

---

**Table 7. Distribution of the teeth of category C according to tooth group, periapical radiolucency, type of restoration and causes for pulpal involvement (u.: upper, l.: lower, ant.: anterior, car.: caries, tra.: trauma, un.: unclear)**

<table>
<thead>
<tr>
<th>Category C</th>
<th>n</th>
<th>Radiolucency</th>
<th>Restoration</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>no</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>u. ant. teeth</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>u. premolars</td>
<td>11</td>
<td>4</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>u. molars</td>
<td>15</td>
<td>8</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>l. ant. teeth</td>
<td>1</td>
<td>1</td>
<td>–</td>
<td>1</td>
</tr>
<tr>
<td>l. premolars</td>
<td>7</td>
<td>6</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>l. molars</td>
<td>14</td>
<td>3</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>total</td>
<td>53</td>
<td>23</td>
<td>30</td>
<td>12</td>
</tr>
</tbody>
</table>
Table 8. Prevalence of apical periodontitis and root canal fillings in Germany compared to some other European countries (ap. perio.: apical periodontitis; Ger: Germany; Neth: The Netherlands; Switz: Switzerland; Swe: Sweden; Nor: Norway)

<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>patient age in years</th>
<th>periapical periodontitis</th>
<th>root canal fillings</th>
<th>% of teeth with ap. perio.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present study</td>
<td>Ger</td>
<td>0 35.2</td>
<td>0.75</td>
<td>3.0</td>
<td>0.67</td>
</tr>
<tr>
<td>Hülsmann et al. (1)</td>
<td>Ger</td>
<td>20 -&gt;60</td>
<td>—</td>
<td>—</td>
<td>0.78</td>
</tr>
<tr>
<td>Hülsmann et al. (2)</td>
<td>Ger</td>
<td>20 -&gt;60</td>
<td>0.82</td>
<td>3.4</td>
<td>0.90</td>
</tr>
<tr>
<td>Klimek et al. (3)</td>
<td>Ger</td>
<td>0 41.1</td>
<td>—</td>
<td>—</td>
<td>0.99</td>
</tr>
<tr>
<td>DeCleen (13)</td>
<td>Neth</td>
<td>20 -&gt;59</td>
<td>1.03</td>
<td>4.5</td>
<td>0.53</td>
</tr>
<tr>
<td>Imfeld (14)</td>
<td>Switz</td>
<td>66</td>
<td>1.18</td>
<td>8.4</td>
<td>2.84</td>
</tr>
<tr>
<td>Eckerbom et al. (15)</td>
<td>Swe</td>
<td>20 -&gt;60</td>
<td>1.28</td>
<td>5.2</td>
<td>3.18</td>
</tr>
<tr>
<td>Odesjö et al. (16)</td>
<td>Swe</td>
<td>20 -&gt;60</td>
<td>0.55</td>
<td>2.9</td>
<td>1.62</td>
</tr>
<tr>
<td>Eriksen &amp; Bjertness (17)</td>
<td>Nor</td>
<td>50</td>
<td>0.87</td>
<td>3.5</td>
<td>1.47</td>
</tr>
<tr>
<td>Eriksen et al. (18)</td>
<td>Nor (1984)</td>
<td>35</td>
<td>0.38</td>
<td>1.4</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35 (1993)</td>
<td>0.15</td>
<td>0.6</td>
<td>0.36</td>
</tr>
</tbody>
</table>

This obvious discrepancy might not only be due to the different patient material examined but also to improper techniques applied by some German dentists combined with poor knowledge on the principles of adequate endodontic treatment focusing on the control and elimination of root canal infection. This assumption might be further supported by the results of the present study that the radiographic appearance of the root canal filling was satisfactory in length and condensation in only 14% of the cases which have not been apicectomized. Most of the root canal fillings were not well condensed (66%) or ended more than 2 mm short of the radiographic apex (56%).

Out of the pulpless, non-endodontically treated teeth, the vast majority (88%) showed radiographic signs of periapical pathosis. In a German population, Hülsmann et al. (2) reported a similar percentage of teeth with radiologically detectable periapical lesions. However, the real percentage may be still higher than the calculated figures as lesions confined to cancellous bone may not be detected in radiographs. Furthermore, it can only be speculated as to the causes for the formation of the diagnosed endodontically induced lesions. Coronal leakage via defect restorations or deep carious lesions and traumatic injuries might explain their occurrence. The smallest percentage of teeth which needed endodontic treatment constituted the cases with an irreversible pulpitis. Most of them had carious lesions compromising the pulp tissue. Molars were predominantly associated with a widening of the periapical periodontal ligament space, indicating a progressing inflammation in radicular portions of the pulp. There was no actual data from other studies concerning the prevalence of teeth with an irreversibly damaged pulp in an adult German population. The endodontic treatment need for the selected patient group can only be estimated if consecutive cross-sectional or longitudinal studies are performed. In the present
study, all teeth of categories B and C (n=175) and
t hose of category A showing clinical symptoms of
periapical periodontitis (n=11) require adequate root
canal treatment (=minimal endodontic treatment
need: 186/7987=2.3%). The question as to whether
a root canal filled tooth with a periapical radiolu-
cency will result in a success or failure cannot be clearly
answered on the basis of a single radiograph repre-
senting only a static image of a dynamic periapical
process at a certain time. However, there are indica-
tions that teeth presenting a periapical radiolu-
cency are more likely to fail when the endodontic
m aintment has been performed more than two years ago
(10). Although no data on the exact time of root can-
 al treatment are available in this investigation, the
time period between endodontic treatment and fol-
low-up probably exceeded two years in many cases.
Furthermore, inferior technical quality of the root can-
 al treatment is reported to be a main cause of en-
dodontic failures (11). It is therefore expected that in
the present study the majority of the periapical
lesions in connection with teeth with unsatisfactory
root canal fillings will not heal. Retreatment may be
an appropriate approach to these teeth. In our study
material, a total of 106 endodontically treated symp-
tomless teeth would have to be re-treated at worst (=
endodontic treatment need: 186+106/7987=3.7%).
Thirty-one teeth demonstrating no clinical or
radiographic signs of periapical pathosis had inade-
quately obturated root canals and an insufficient
coronal seal. They should be re-treated prior to re-
storative procedures according to the guidelines of
the European Society of Endodontology [12]. Ac-
cordingly, the estimated endodontic treatment need
related to the total number of examined teeth would
approximate to 4.0% [= (186+106+31)/7987].
The teeth of category D were not considered in this
calculation. Nevertheless, there is evidently a substi-
tial need for endodontic treatment and retreatment in
the selected German population. In comparison with
the figures derived from other western countries
(Table 8), the high prevalence of endodontically
treated teeth associated with radiographic signs of
periapical periodontitis along with the poor quality of
the root canal filling deserves particular attention.
It seems to be justified that additional educational ef-
forts at the undergraduate level are necessary to im-
prove the standard of endodontic treatment in Ger-
many. In addition, dental practitioners should be
motivated to attend continuing education courses on
clinical endodontics to update their knowledge and
to enhance the quality of diagnosis and endodontic
techniques.

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