# Factors affecting the outcome of orthograde root canal therapy in a general dentistry hospital practice

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***Objective.*** The goal of this study was to weigh the impact of patient-related, tooth-related, and treatment-related factors on therapy outcome in a series of consecutive patients.
***Study design.*** Eighty-four patients were included. Of these, 66 (79%) were available for recall after $\geq$ 30 months (mean = 46 months). Root canal treatments were performed using a standard protocol. At recall, teeth were scored by means of the periapical index (PAI), which was the dependent variable (dichotomized to sound/ unsound). Explanatory variables were patient age, integrity of the nonspecific immune system, smoking status, dichotomized PAI score before treatment, initial treatment versus retreatment, prior exposition of the root canal to saliva, stainless-steel hand versus NiTi rotary instrumentation, and quality of root filling. Unit of observation was the patient-individual. Data were analyzed using univariate tests and backward stepwise logistic regression analysis.
***Results.*** After 5 steps with elimination of the least significant independent variable, status of the immune system ($P = .05$), initial PAI ($P = .04$), and root filling quality ($P = .01$) were found to be the indispensable predictors for treatment outcome. Using these 3 explanatory variables, the logistic regression model had a predictive value of 87%, compared to 91% with all 8 variables. Success rate at recall (PAI $\leq$ 2 without symptoms) was 88% (95% CI = 78, 94).
***Conclusion.*** The integrity of a patient's nonspecific immune system, which has been neglected in earlier investigations, is a significant predictor for endodontic treatment outcome, and should receive more attention in future studies.
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Ever since Strindberg's groundbreaking work on "the dependence of the results of pulp therapy on certain factors,"[1] a plethora of clinical follow-up studies has dealt with influencing factors on endodontic treatment outcome.[2] The aim of endodontic therapy is to prevent or treat periapical inflammatory lesions. These are host reactions to microbial challenges from the root canal system.[3] It has been convincingly demonstrated that a maximal reduction of microbiota in the root canal system, followed by a tight seal, are key factors to endodontic treatment success.[4] On the other hand, with few exceptions,[1,5] host factors other than patient age and gender have been largely neglected in clinical investigations.

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The goal of the present follow-up study was to assess the influence of patient-related, tooth-related, and treatment-related factors on endodontic outcome in a series of consecutive patients, and weigh these variables against each other using logistic regression analysis.

## PATIENTS AND METHODS

### Cohort identification

Subjects included in this study were patients seeking treatment at the dental service of the Policlinique Medicale Universitaire in Lausanne. During her part-time employment as a comprehensive dental care provider at the hospital, one of the authors (M.M.) completed 132 orthograde root canal treatments (RCT) in 42 incisors, 17 canines, 41 premolars, and 32 molars in 84 patients (46 males and 38 females, aged 12 to 86, mean = 41). For the analysis of clinical study data, the unit of observation was the patient-individual. This was considered a statistical necessity since in the current study patient-related factors were taken into consideration. In patients with more than 1 RCT, the tooth to be analyzed was randomly selected by throwing dice. The diagnoses of the 84 study teeth were pulpitis: 20, vital in need of RCT for prosthetic reasons: 5, necrotic with lesion: 32, nonsensitive to cold test in need of RCT for prosthetic reasons: 11, insufficient RCT with lesion: 11, insufficient RCT without lesion: 5.

An attempt was made to follow up all cases. To attract patients for recall appointments, an offer of a free follow-up examination of the involved tooth/teeth was given. Attempts to recruit patients for recall were made via telephone and/or mail. Follow-ups for data analysis were obtained after a minimum of 30 months (mean ±/ SD = 46 ±/ 12 months). This allowed the preexisting periapical lesions adequate time to heal.[1,6] Informed consent was obtained from all patients to use coded information pertaining to their health status for this study.

## Endodontic treatment procedures

RCTs were performed according to each individual's synoptic treatment plan, ie, not in teeth with severe attachment loss, diagnosed root fractures, or in patients with low compliance. The operating clinician had more than 5 years of postgraduate experience in endodontics prior to this investigation. Furthermore, she had been involved in teaching rotary instrumentation to general practitioners. A standardized protocol was applied, using rubber dam isolation and aseptic technique. After the removal of defective restorations, temporary fillings, and/or caries, treatment fields were cleansed with 3% hydrogen peroxide and Dakin's solution (0.5% sodium hypochlorite buffered with sodium bicarbonate, pH 9). Canal orifices were flared with Hedström files and Gates-Glidden drills. An electronic apex locator (Bingo-1020, Forum Technologies, Rishon Lezion, Israel) was used to assess working length, which was verified radiographically. Working lengths were set 2 mm and 1 mm short of the canal orifice for vital and nonvital teeth, respectively.[7]

Instrumentation was either carried out with stainless steel K-files (Maillefer-Dentsply, Ballaigues, Switzerland) using the step-back technique, or by nickel-titanium (NiTi) rotary instrumentation (ProFile OS, .06/.04, Maillefer) according to the manufacturer's instructions. The choice of instrumentation technique was not randomized, but simply a matter of availability of accessories for rotary instrumentation. During preparation, canals were irrigated with Dakin's solution after each instrument. Roots with a necrotic pulp or re-treatment cases were treated in 2 or more appointments. A calcium hydroxide paste (Pulpdent Corporation, Watertown, Mass) was applied to the canal system with a lentulo spiral for the interim. Access cavities were sealed with IRM (Dentsply, Konstanz, Germany). Whenever vital pulps were treated in more than 1 visit, calcium hydroxide was used as an interappointment dressing. Teeth were root-filled using cold lateral condensation with gutta percha and Pulp Canal Sealer (Kerr Manufacturing Co, Romulus, Mich). After the roots had been filled, canal orifices were covered with glass ionomer cement (Ketac-Fil Plus Aplicap, 3M-ESPE, Seefeld, Germany). If time allowed, a definitive restoration (amalgam or composite) was placed during the root-filling appointment. If not, teeth were sealed with glass ionomer cement (Ketac, 3M ESPE), with permanent restorations or core build-ups being placed in the next appointment.

## Data collection

Anamnestic, diagnostic, and treatment information (see below, "Assessment of explanatory variables") for each patient was entered onto a collection form and coded for computer entry. Tooth sensitivity was assessed using carbon dioxide snow. At the initial visit, after completion of the RCT and at the follow-up visit, standardized radiographs were taken. Conventional radiographs (Eastman Kodak Co, Rochester, NY) were obtained using a film holder for paralleling technique. Exposure times and kilovoltage were adjusted according to the film manufacturer's instructions.

## PAI scoring

In the current study, periapical health was assessed radiographically using the periapical index (PAI) system.[8] Two observers (M.M., M.Z.) were calibrated against a "gold standard" set of 100 reference radiographs kindly provided and prescored by the developers of the index. Using a visual analogue scale, these radiographs were scored once by each observer. Subsequently, results were discussed between the observers in relation to the "gold standard." Reference radiographs were then rescored twice in 2-week intervals, and interobserver and intraobserver agreements (weighted kappa values) were calculated based on these scores.[9]

For this study, initial and follow-up radiographs were individually evaluated under standardized conditions by 2 observers using a table slide viewer. For multirooted teeth, the highest of the PAI scores given to the individual roots was used. In case the 2 observers did not agree, the higher of their scores was assigned.

## Assessment of explanatory variables

A series of factors was recorded at the beginning of and during the current study in order to test their impact on treatment outcome.

*Patient-related factors.* Age (numerical) and integrity of the nonspecific immune system (dichotomized) were noted for each patient. Conditions and consequential medications, suggesting an impaired nonspecific immune system in the current patient material, are listed in Table I. Patients included in the "compromised ns immune system" group suffered from a condition, underwent treatment, or took medication interfering with neutrophil or monocyte/macrophage

**Table I.** Conditions associated with impaired non-specific immune responses (NSR) found in the current cohort

| *Patient #* | *Condition(s)* | *Medication interfering with NSR* |
|---|---|---|
| 16 | Insulin-dependent diabetes, kidney insufficiency | |
| 23 | Breast cancer | Cytostatic drugs |
| 36 | Gastritis* | |
| 37, 83 | Noninsulin-dependent diabetes, gastritis* | |
| 43 | Colitis* | |
| 47 | Rheumatoid arthritis, reflux esophagitis* | |
| 59 | Insulin-dependent diabetes | |
| 61 | Gout | Steroidal anti-inflammatory drugs |
| 70 | Ulcerative Colitis | |
| 72 | Ulcer*, reflux esophagitis* | |
| 84 | Ulcer*, rheumatoid arthritis | |

*Clinical manifestations of diagnosed stress-induced disorders.[12]

function during the recall phase. Patients suffering from diagnosed stress-induced disorders with gastrointestinal tract manifestations were included in this group,[10] based on the well-established correlation between chronic stress and nonspecific immune function.[11,12] The "intact ns immune system" group consisted of healthy patients or individuals presenting with medical conditions that are not associated with impaired nonspecific immune responses. Thirdly, smoking status of the patients under investigation was recorded: current smokers versus individuals who either had never smoked or had quit smoking more than 1 year previously.

*History of the tooth under analysis.* It was noted whether the treated tooth received an initial RCT or whether it was a retreatment case. Secondly, the PAI score on the initial radiograph was entered into the analysis form to assess the impact of the preexisting periapical status on treatment outcome. PAI scores were dichotomized: 1 and 2 were termed "sound," 3 to 5 "unsound."[8] Initial PAI scores were used instead of other diagnostic data such as tooth vitality, because a variety of different conditions were endodontically treated (see above). The radiographic appearance of the periapex provides a relatively accurate estimate of the microbial load in the root canal system,[3] and was thus chosen. Thirdly, it was recorded whether the tooth had been left open during a previous emergency visit with another dentist, which is a common practice with Swiss dental practitioners to treat acute apical abscesses. These teeth had been deliberately exposed to salivary contamination for several days under the assumption that drainage through the root canal may alleviate postoperative pain and/or reduce swelling.

*Treatment variables.* Hand instrumentation was compared to rotary instrumentation. After completion of the RCT, it was noted whether the root filling fulfilled the radiographic quality goals, ie, whether proper length control was achieved and the root filling was free of voids (radiolucent areas in the root filling of more than 1 mm in diameter were considered to represent voids).

### Data analysis

Associations among explanatory variables were assessed with multiple chi-square analyses with a level of significance adjusted according to Bonferroni's method.

Bivariate analyses were further performed to compute correlations of one of the explanatory variables and the outcome (PAI $\leq$ 2 vs PAI 3-5). However, due to the low number of cases not healing, expected frequencies were $<5$, rendering the analysis noninterpretable.

Finally, logistic backward stepwise regression analysis was performed to assess the influence of independent variables on treatment outcome (dichotomized PAI score at recall = dependent variable). The explanatory independent variables were (1) patient age, (2) status of nonspecific immune system, (3) smoker/ non-smoker, (4) initial treatment/retreatment, (5) initial PAI, (6) tooth left open during emergency treatment (yes/no), (7) type of instrumentation, and (8) quality of root filling. All explanatory variables other than patient age were dichotomous (Table II).

## RESULTS

### Drop outs

With 18 patients clinical and radiographic follow-up examinations were not possible. Of these 18, 1 was deceased, 4 had unknown residence at the time of recall, 7 had moved abroad, 5 were not interested, and 1 gave no reply upon request. For the remaining 66 patients (79 %), follow-up data were recorded. The distribution of explanatory variables was statistically similar comparing drop outs and individuals available for recall (Table II).

### Observer agreement

At the third scoring session, weighted kappa levels for the agreement with the "gold standard" score were 0.83

**Table II.** Distribution of dichotomized independent variables among cohort

| *n patients* | | |
|---|---|---|
| Integrity of ns immune system | intact: 54 (17)* | compromised: 12 (1) |
| Smoking status | non-smokers: 41 (10) | smokers: 25 (8) |
| Salivary contamination | no: 58 (13) | yes: 8 (5) |
| Initial PAI | 1 or 2: 32 (10) | 3 to 5: 34 (8) |
| Treatment type | initial RCT: 53 (15) | retreatment: 13 (3) |
| Type of instrumentation | rotary: 22 (4) | hand: 44 (14) |
| Root-fill quality | good: 49 (15) | poor: 17 (3) |

*Distribution in 66 cases with a follow-up (values for 18 drop outs in parenthesis).

**Table III.** Stepwise logistic regression analysis

| | | β | *SE* | *P* | *Odds ratio* |
|---|---|---|---|---|---|
| Step 1 | Age | 0.05 | 0.04 | .22 | 1.06 (0.97, 1.15)* |
| | Immune system | 3.48 | 1.80 | .05 | 32.49 (0.96, 1099.8) |
| | Smoking status | −0.23 | 1.17 | .85 | 0.80 (0.08, 7.93) |
| | Salivary contamination | 1.22 | 1.29 | .34 | 3.39 (0.27, 42.49) |
| | Initial PAI score | 2.18 | 1.33 | .10 | 8.85 (0.65, 119.71) |
| | Treatment type | −0.47 | 1.29 | .71 | 0.63 (0.05, 7.38) |
| | Type of instrumentation | 0.68 | 1.19 | .57 | 1.97 (0.19, 20.42) |
| | Root-fill quality | 2.78 | 1.16 | .02 | 16.05 (1.65, 155.66) |
| Step 6 | Immune system | 2.11 | 1.09 | .05 | 8.25 (0.98, 69.19) |
| | Initial PAI score | 2.52 | 1.23 | .04 | 12.45 (1.12, 138.38) |
| | Root-fill quality | 2.55 | 1.01 | .01 | 12.77 (1.75, 93.10) |

*PAI,* Periapical index.
The degree of freedom was 1 for all variables; *95% confidence intervals.

for M.M. and 0.76 for M.Z. The intraobserver agreement scores gave weighted kappa values of 0.82 (M.M.) and 0.73 (M.Z.). The interobserver agreement scores resulted in a weighted kappa of 0.68. All weighted kappa values indicated good agreement.[9]

### Analysis

Two teeth had acute periapical exacerbations before the minimal follow-up period. In 1 case this occurred at 1 month. In the other case it occurred 15 months after completion of the RCT (Fig 1). These teeth were assigned an "unsound" outcome, and they were included in the analysis. No other teeth showed any symptoms at recall, ie, after $\geq$ 30 months. The overall success, defined as PAI score at recall $\leq$ 2 without symptoms, was 88% (95% Confidence Interval [CI] = 78, 94).

No significant correlations were found between the explanatory variables in univariate analyses. A regression model was constructed and in 5 steps reduced from the original 8 variables to 3 (Table III). Reducing the model to 2 variables would have significantly reduced its overall predictive value. The model with the 3 indispensable variables had a predictive value of 87%, compared to 91% with all 8 explanatory variables in the equation. The 3 predictors for treatment outcome in the current cohort were the following: integrity of the nonspecific immune system ($P$ = .05), dichotomized initial PAI score ($P$ = .04), and root-filling quality ($P$ = .01).

## DISCUSSION

The current study revealed that the immune status of the patient, initial PAI score, and the radiographic quality of the root filling had a large influence on therapy outcome in the current cohort. Patient age, smoking status, initial treatment versus retreatment, whether the root canal system had been deliberately exposed to salivary contamination prior to treatment, and the type of instrumentation had negligible impact.

The overall recall rate of 79% compares favorably with other investigations.[2] In the present study, 1 operator performed standardized treatments; factors not assessed in the regression analysis could thus be better controlled than in retrospective studies with pooled data from a clinic. However, the number of root-treated teeth was limited, and statistical power consequently low. Only 8 of the 66 teeth followed were not sound at recall. It is an inherent problem with clinical endodontic studies in general that most cases heal when proper clinical concepts are respected, and thus a vast number of patients need to be followed to give conclusive results. For instance, the odds ratio for high-quality root fillings to result in a sound PAI score at recall was 12.8. This

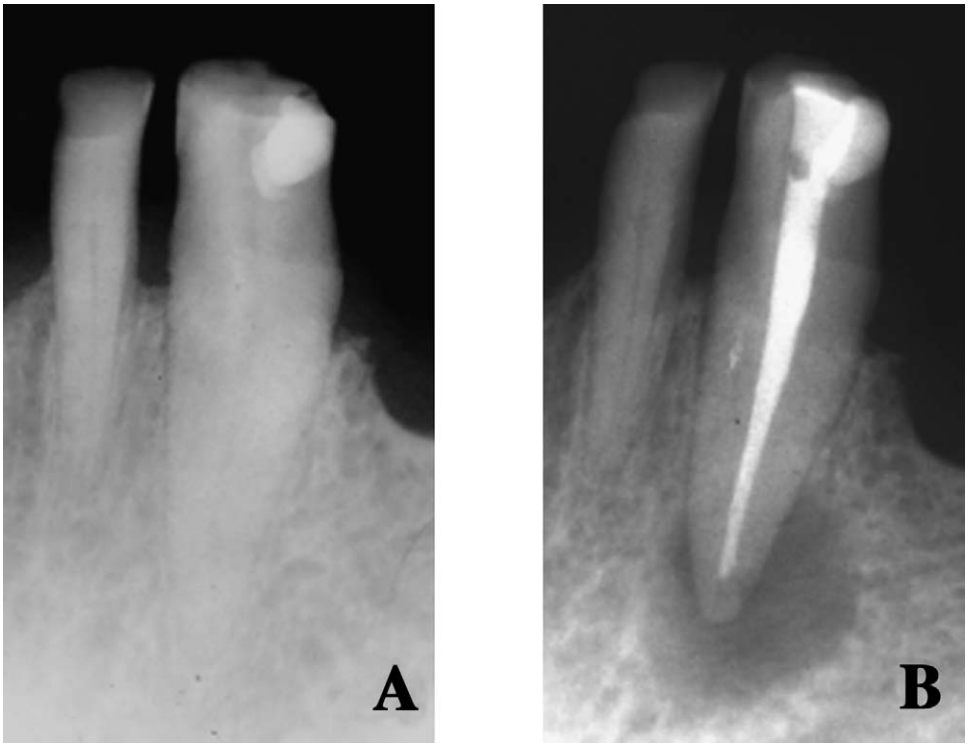


Fig 1. One of the early failures in the current cohort. The tooth was vital when endodontic treatment was initiated, and no periapical process was visible (**A**). Fifteen months later, an acute periapical exacerbation with a rather large radiolucency had developed. The patient belonged to the compromised ns immune system group (Table I, #84).

indicated that, based on the current patients, it was 12.8 times more likely to obtain a favorable outcome with a good-quality root filling than with a nonperfect one (Table III). However, the 95% CI ranged from 1.8 to 93.1, which means that with 95% certainty, repeated investigations with similar cohorts would yield odds ratios in that range for the "quality of root filling" variable. Following a higher number of patients would narrow confidence intervals, allowing extrapolations from the study cohort on the general population with a higher degree of certainty.

Nevertheless, interesting information may be drawn from the current investigation. Some of the independent variables assessed were either new or at least not yet investigated in any endodontic outcome study. For instance, the influence of smoking status on endodontic treatment outcome has not yet been described. Based on the current results it may be surmised that large patient numbers are necessary to reveal such a correlation, if it exists at all. This is in line with a recently published epidemiologic study.[13] Further, this would be the first clinical study to compare hand instrumentation using stainless steel files versus rotary instrumentation. As may be expected from microbiologic investigations,[14] no significant impact of instrumentation type on outcome was found.

The influence of leaving a tooth open after emergency treatment on long-term periapical outcome has only been assessed in 1 follow-up study.[15] As in the present cohort, no significant difference was found between teeth that, at one point, experienced deliberate salivary contamination versus teeth that did not. This is somewhat surprising. Leaving a tooth open for several days may not make it more prone to develop a treatment-resistant infection, if stringent antiseptic strategies are subsequently followed.[16] However, this problem needs further clarification before definite statements can be made. As of yet, the source of treatment-resistant microbiota in the root canal system is not clarified.[17] Nevertheless, there is a higher prevalence of enteric microorganisms in cases left open between visits, and it is not clear how this may influence prognosis.[18]

Whether the RCT was an initial treatment or a retreatment did not significantly influence outcome. The tentative reason for this was that the retreatment cases in this study were relatively simple, with little transportations in the canal system by the previous dentist. It has been demonstrated that such simple retreatments have success rates similar to initial treatments.[19] Therefore, the current data should not be extrapolated to retreatment cases in endodontic specialist practices.

The importance of the initial periapical status and the radiographic quality of the root filling on treatment outcome has been pointed out in several follow-up studies.[2] Five of the 8 cases with a PAI greater than 2 at recall had overfills. However, 4 of these teeth were free of symptoms (1 was one of the early failures). From these 4 teeth, 3 showed a 1-step decrease in PAI score, whereas 1 remained stable. Based on long-term follow-up studies, it may be assumed that these cases will heal radiographically at a later point in time.[20]

Probably the most important finding of the current investigation was the impact of an impaired nonspecific immune system on treatment outcome. Strindberg in his follow-up study included the general health state of the patients under investigation as an explanatory variable; however, he found no significant impact.[1] In the current study, based on more recent knowledge on the nature of inflammatory diseases,[21] it was attempted to specifically discern between patients with tentatively impaired nonspecific immune responses versus patients with other conditions (or none at all, for that matter). This being a hospital-based study, the health information given by the patients can be regarded as being relatively accurate. However, blood tests were not performed, and *bias* can therefore not be excluded. Nevertheless, the current results are in line with recently published data from a retrospective study with diabetic versus nondiabetic patients.[5] Animal studies have shown that immunocompromised rodents have a higher risk of systemic spread of an endodontic infection[22] and develop larger periapical lesions[23] compared with healthy counterparts. However, no investigations have addressed the *healing* of such lesions after root canal treatment, which could be an interesting task for future studies.

In conclusion, it may be stated that this investigation raised some interesting information pertaining to factors, which may or may not affect endodontic treatment outcome. However, this being a prospective observational study without randomization (as the vast majority of clinical endodontic studies are), the level of evidence gained from the current data is limited. The need for randomized clinical trials can therefore not be overestimated.

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