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A DYNAMIC PROSPECTIVE COHORT STUDY OF INITIAL ENDODONTIC TREATMENTS OF 627 TEETH: LONG TERM RESULTS

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ABSTRACT:

Objective. The purpose of this dynamic prospective cohort study was: 1) to follow-up a large number of initial endodontic treatments performed by a single operator, periodically checked over a 12-years period, using a zinc oxide-eugenol-formaldehyde endodontic cement; 2) to correlate outcome to a number of clinical variables and 3) to correlate outcome to Toronto studies outcome.

Study design. This prospective study included all consecutive cases the author had been treating from 2000 to 2010, period with a follow-up to 10-years.

Results. The overall rate of success ranged from 98% at first year follow-up to 85% at ten year follow-up. The recall rate varied from 90% of the first year to 52% of the 10 year. The success rate was not correlated with status of the pulp, sex and gender and type of root filling. The success rate was negatively correlated with posterior teeth and with the absence of full coverage. The overall success rate a 4-6 years follow-ups was higher than in Toronto studies.

Conclusions. The obtained long-term success rate was comparable to other studies, notwithstanding root canal treatments have been performed in a general dental practice by a low-experienced clinician.

Key words: formaldehyde, endodontic, cohort, prospective

INTRODUCTION:

Several cohort studies have been published evaluating success and failure of teeth endodontically treated [1 - 5]. The reported success rates have been varying from 40 to 97%. The wide range in success rate may depend on differences in experimental design and clinical procedures, criteria for evaluation of success, the length of the postoperative observation period (follow-up period) and the recall rate (drop-outs) [6].

This diversity of outcome is confusing for the clinician seeking evidence of the benefits of endodontic therapy as a foundation for clinical decision-making.

We can estimate success on the basis of different diagnostic tests and on the basis of time of application of these diagnostic tests. Thus success is a multidimensional concept.

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To classify success, we may distinguish 5 spatial dimensions of success:

- **survival**: tooth present in the mouth

- **clinical success**: tooth present and functional in the mouth in sound or yet restorable condition, with no clinical signs and symptoms of apical periodontitis

-**two-dimensional radiographical success**: assessed by means of periapical radiographs. No sign of periapical radiolucency

-**three-dimensional radiographical success**: assessed my means of Fan Beam or Cone Beam radiology. No sign of periapical radiolucency

- **histological success**: absence of tissue inflammation assessed by means of a biopsy of periapical tissue and subsequent microscopic observation (being destructive test is possible generally in post-mortem study)

Each of these five spatial dimensions of success has a temporary dimension: the success as times goes. We'll call it temporal success.

The success rate diminishes going from clinical through radiographic to histological evaluations, and decreases with time.

The aim of the present study was to measure clinical success of teeth endodontically treated in relation to the time of observation. The study was devised to fill the void in the dental literature about long term clinical efficacy of endodontic cement containing formaldehyde and to confront it with the success obtained with other endodontic materials and procedures. Zinc oxide-Eugenol-formaldehyde cement, introduced in 1954 by Richter and Sargenti with the name of N2, has been always an issue of controversy, owing to the presence in the formulation of formaldehyde. In the present study this cement was used with a Sargenti's modified technique, as described later on in material and methods.

This study adopted the clinical success as estimate of outcome, considering the most useful parameter for clinical choices, above all in the era of implants.

It is a dynamic prospective cohort study over 12 years period on all the patients addressed in the office needing endodontic therapy. The office utilized was a general dental practice in a rural village of 8.000 inhabitants in Italy. The consecutiveness of the patients treated over that long period of time minimized biases derived from selection of patients and maximized the randomization of the sample. The bias derived from the absence of blindness and all the consequences arising from it still exist. Yet the presence of drop-outs adds to the study a further degree of distortion, being not able to exclude that some drop out reasons are related to the outcomes.

MATERIAL AND METHODS:

Criteria of selections of patients in the study: All the patients consecutively admitted to the office, needing

endodontic procedures. The criteria of exclusion were:

- third molars

-teeth not restorable or with bad restorative prognosis: this criterion is obviously changed with time as the operator's experience increases. In the first years in this study there were more unrestorable teeth or those with bad restorative prognosis than later and today. Besides this criteria is not easily comparable with other studies.

-mouth opening incompatible with endodontic operative procedures (2 cases were excluded for these reasons)

-economic reasons

Cohort:A total of 626 teeth received initial endodontic treatment. The patients have been treated in a private general dental office (Mirabella Eclano, Italy) consecutively during the period 2000-2010 and were re-examined (during routine control visits) until December 2012.

All patients were diagnosed and treated using routine techniques, which have been used from more than 50 years in dental practice and have been abundantly described in dental literature. Thus ethical approval was not sought, according to Italian legislation (d.lgs. n. 200 del 6.11.2007; d.lgs. n. 211 del 2003 e d.m. 12.5.2006), which clearly excludes the need of ethical approval for observational studies using routinary drugs or therapies. Informed consents were obtainend from patients in written form.

The distribution of the material according to type of treated teeth, controlled teeth, recall rate (drop-outs), followed-up patients and prognostic factors are presented in Table 1 and Table 2

Original Endodontic Procedure: In order to formulate a diagnosis, besides a scrupulous clinical exam, at least one diagnostic radiograph was performed. The pulp diagnosis of "vital" or "necrotic" (suspected with clinical and radiologic tests) was confirmed on the basis of the observation of continuous blood-filled pulp tissue in the root canal orifice(s), regardless of the clinical appearance of the tissue contained in the pulp chamber.

All treatments were performed with a rubber dam. The pulpectomies were performed with Hedstrom files under local anaesthetic. The widening and shaping of the canals were done with a step-back technique. Thin K files were used initially. Subsequently Hedstrom files were used to widen and shape the canals, along with Gates Glidden drills. During the preparation, the canals were frequently irrigated with 5% sodium hypochlorite solution.

In the vital cases efforts were made to leave apical pulp tissue of about 2-4 mm in length: a working length 2-4 mm shorter than to the radiographic apex and checked not to be at the apical foramen by means of an apex locator (Apex Finder, Kerr).

The pulp was completely removed in cases in which there was necrosis: in these cases, the working length was

estimated considering the apical foramen as terminus of shaping according with the results of apex locator (using a file 0.15 or bigger). In doubt, a second radiograph with a file inside the canal permitted a more accurate measurement.

A cotton pellet impregnated with Cresatin was used as a dressing between some treatments needing two appointments. In 20 necrotic cases, Potassium iodide (2%, 5%) was used. The access cavities were sealed with zinc oxide eugenol cement (Cavit G).

The canals were filled in the following way:

-zinc oxide-eugenol-formaldehyde endodontic cement (N2 cement - Ghimas, Italy) and a single cone of gutta-percha (0.2 taper), or (less frequently) Thermafil (Dentsply/Maillefer), when apical diameter was less than 0.3 mm

-only zinc oxide-eugenol-formaldehyde cement (N2 cement - Ghimas, Italy) applied with a lentulo filler in larger canals, when apical diameter was equal or larger than 0,3mm

The treatment of vital teeth was performed generally in single appointment. The treatment of necrotic teeth was performed generally in 2 appointments.

The treatments were all and entirely performed by one operator from endodontic to restorative phase. This has eliminated the inter-operators variability, but not the variability intra-operator (e.g. during the years, the criteria for "restorability" of a tooth has changed).

Criteria adopted for determining success and failure

The clinical success was assessed in this study on the basis of the following criteria:

- tooth in function

- no pain either spontaneous or evoked by chewing or gingival palpation

- no swelling

- no pus drainage

- no fistula

- no mobility incompatible with chewing

The cases which did not fulfil all the above criteria were considered failed, though surviving in the mouth.

There were classified 3 categories of failures:

- **endodontic failure**: presence of clinical symptoms and signs of apical periodontitis (pain, swelling, pus drainage, presence of fistula etc.)

-**mechanical failure**: non-restorable fracture of the tooth-restoration complex

- **periodontal failure**: tooth needed to be extracted owing to irreversible periodontal problems (e.g. mobility)

Data Management and Statistical methods

Statistical analysis was performed in the following ways:

(a) Univariate description of the data

(b) Bivariate associations between the treatment outcome and prognostic variables, using contingency tables and Chi-square test or Fisher's exact test.

The dependent variable for these analyses was the dichotomous outcome: overall success rate versus overall failure rate, endodontic success rate versus endodontic failure rate, mechanical success rate versus mechanical failure rate, etc.

Of the prognostic variables considered 5 were dichotomous (gender, age group, pulp vitality, root filling, prosthetic crown) and 1 was trichotomous (tooth type).

All statistical tests were performed as two-tailed and interpreted at the 5% significance level

Being a controlled study of dynamic type (patients had been coming in during a ten years period), solely for simplifying the statistical analysis of failures in relation to the prognostic variables, It was considered that the success rate in the drop-out group to be the same as success rate in the controlled group.

By means of chi-square text and Fisher's exact test, the following hypotheses (H0) were tested:

1) The clinical success rate is not related to the sex of patients (contingency table 1)
2) The clinical success rate is not related to the age of the patients (contingency table 2)
3) The endodontic success rate is not related to the type of root filling (contingency table 3)
4) The endodontic success rate is not related to the type of tooth (contingency table 4)
5) The endodontic success rate is not related to the preoperative state of the pulp (contingency table 5)
6) The endodontic success rate of upper first molars with 3 canals shaped and filled is the same of upper first molars with 4 canals shaped and filled (contingency table 6)
7) The mechanical success rate of treated molars is the same of that of premolars (contingency table 7)
8) The mechanical success rate of treated teeth is not related to the presence of prosthetic crown (full coverage) (contingency table 8)
9) The mechanical success rate of treated molars is no related to the presence of prosthetic crown (full coverage) (contingency table 9)
10) The mechanical success rate of treated premolars is not related to the presence of prosthetic crown (contingency table 10)
11) The clinical success rate observed in the Toronto Studies (4-6 year follow-up) is not different from the clinical success rate observed in the present study (contingency table 11).

RESULTS:

The teeth classified as failed were 31, whereby 26 were extracted during the observation period. Thus 5 failed teeth survived without further therapies.

The clinical success rate of treated teeth, the endodontic success rate and the prevalence and incidence of failures during the observation period are shown in Table 3.

As said in the description of adopted statistical analysis, being a controlled study of dynamic type (patients had been coming in during a ten years period), solely for simplifying the statistical analysis of failures in relation to the prognostic variables, it was considered that the success rate in the drop-out group to be the same of success rate in the controlled group). Therefore, from the failures observed in the controlled group it was calculated the failures expected in the entire treated sample. (Tables 4 – 8)

In Table 9 it is shown the distribution of type of failures in relation to the year of happening. It is an esteem of the incidence of failures.

Contingency Table with chi-square test and Fisher's exact test

The calculation of chi-square test and Fisher's exact test are shown in Contingency table I – XI.

Null hypotheses (H0) not rejected**:**

- The clinical success rate is not related to the sex of patients (contingency table 1)
- The clinical success rate is not related to the age of the patients (contingency table 2)
- The endodontic success rate is not related to the type of root filling (contingency table 3)
- The endodontic success rate is not related to the preoperative state of the pulp (table 5)
- The endodontic success rate of upper first molars with 3 canals shaped and filled is the same of upper first molars with 4 canals shaped and filled (contingency table 6)
- The mechanical success rate of crowned (full coverage) molars is the same of uncrowned molars (table 8-9)

Null hypotheses (H0) rejected**:**

- The endodontic success rate is not related to the type of tooth. (contingency table 4)
- The mechanical success rate of molars is the same of that of premolars (table 7)
- The mechanical success rate of treated premolars is not related to the presence of prosthetic crown (contingency table 10)
- The clinical success rate observed in Toronto Studies (4-6 year follow-up) is not different from the clinical success rate observed in this study (table 11)

DISCUSSION:

At the end of 1999 the author earned the degree of Dentist and at the beginning of 2000 settled a general practice with obviously a very limited experience. So it must be considered that the outcome at 9 and 10 years follow-ups concern the therapies have been concluded during the years 2000-2001-2002-2003. The decisional and operative skills of the author had to be considered upon the outcomes.

This study was conducted to fill up the void present in dental literature about the clinical efficacy on long run of endodontic cements containing formaldehyde. Until today, notwithstanding the widespread use of N2 amidst many dentists around the world from the time of its introduction by Richter and Sargenti in 1954, no prospective study has been performed to assess the clinical validity, besides short-term observations and retrospective studies. [7-8] The most important work is from Telander (1966), who performed a retrospective study with a follow-up of 6 years on 128 vital teeth (recall rate 85%) endodontically treated according to Sargenti's method, obtaining a clinical success rate of 97% and radiological-clinical success rate of 92% [7].

Interestingly, Eriksen noted in a survey of reports on prevalence of apical periodontitis that success rates of endodontic treatment in two European countries, where formaldehyde-containing dressings are widely used, were higher than that in countries where the so called "biocompatible" approaches to endodontic therapy are advocated [9].

The success of endodontically treated teeth is conditioned on numerous variables, especially microbial and mechanical. An overwhelming evidence correlates the endodontic failure (apical periodontitis) with microbial presence inside the root canal system and the mechanical failure (crack and fracture) with residual dentin [10,16-17].

In 1965 Kakehashi et al. showed that no apical periodontitis developed in germ-free rats when their molar-pulps were kept exposed to the oral cavity, as compared with control rats with a conventional oral microflora in which massive periapical radiolucencies occurred. [11]

Having the root canal system a complex geometry not entirely approachable by means of current instruments and techniques, we shall get at the end of the cleaning and shaping procedures a root canal system yet scattered with microorganisms and pulp remains. According to Nair, In the light of the anatomical complexity of the root canal system and of the organization of the flora as biofilms in inaccessible areas of the canal system, it is not feasible to eliminate all the organic content and microorganisms by means of current instruments and techniques. [12] Besides, the histological studies conducted independently by Nair et al. (2005) and Ricucci et al. (2009) have shown that root canal obturation fails to entomb residual bacteria in the root canal system and then

prevent their access to the periradicular tissues to induce or maintain disease [12 - 13].

Formaldehyde owns microbicidal properties and, being a gas, its actions works not only in contact but also at distance from the point of application (Broisman et al. described this property as "vapor effect") [14]. This property is useful in endodontic at light of Nair's and Ricucci's studies. Formaldehyde could reach microbes and pulpal remains located in inaccessible recesses and diverticula of instrumented main canals, the intercanal isthmus, and accessory canals. This property might explain wherefore it is frequent to observe periapical healing also when the canal is not negotiable along the entire length.

Lai e coll. [15] evaluated the antimicrobial properties of commonly used endodontic sealer against four facultative anaerobic species (Streptococcus mutans, Streptococcus sanguis, Escherichia coli, and Staphylococcus aureus) and four obligate anaerobic species (Porphyromonas gingivalis, Porphyromonas endodontalis, Fusobacterium nucleatum, and Prevotella intermedia), finding N2 proved to be the most effective against the microorganisms.

Formaldehyde, being and alkylating agent, has the property of fixation of non vital tissue, as necrotic pulp, thus avoiding that this tissue can become a pabulum for microorganisms. This property is useful, knowing that at the end of the cleaning and shaping procedures some pulp remains shall be left inside the root canal system.

In table 10 it is summarized the outcome of the present study and the Toronto studies, considering the clinical success rate (as reported in the original papers).

In the Toronto studies [1-4] the authors excluded teeth (n=80) having had being extracted during the follow-up period for different reasons (periodontal problems, restorative problems and unknown reasons in some cases).

The overall clinical success rates in the Toronto studies have been recalculated with the inclusion in the data also the teeth extracted, in order to better confront the results with those of the present study, as shown in table 11.

The contingency table 11 shows a highly statistical better outcome in the present study at 4 and 6 years, than in Toronto studies ($p<0,01$), notwithstanding the low skill and experience of the author and the absence of any kind of magnification during the endodontic procedures. This could be attributed, besides the direct activity of formaldehyde contained in N2, to the more conservative approach in shaping cavity access and root canal system. In vital teeth, instrumenting short of the anatomic apex, formaldehyde allows a more conservative access cavity and canal shape with obviously minor dentin sacrifice. This is undeniable an advantage for long term prognosis of tooth [16-17] . We know that mechanical failure (cracks and fractures) of endodontically treated teeth is the major

cause of failures. Also in the present study the mechanical failures were more frequent than endodontic failures. Dentin is the ultimate result of natural selection. Its thickness, its morphology, its ultrastructure are the ultimate products, over millions of years, of Nature Teleology. Evolution has selected these properties in order to endure mastication loads for the entire life of humans. Besides, human development has selected the pulp in order to produce dentin (primary dentin) and repair it (secondary dentin). An endodontically treated tooth has lost its ability to repair dentin, having lost pulp cells. Dentin reparation has two fundamental roles: reinforce the tooth and diminish leakage. Thus, in a tooth already mutilated due to caries and due to the loss of pulp, we need to be careful to sacrifice further dental structure! A tooth with bacteria in the root canals can rely on periapical tissue for healing. Instead a tooth with scarce dentin cannot rely on any reparative process. Therefore a formaldehyde sealer allows the clinician to be more conservative in relation to dental structure.

Drop-out (recall rate) is another cause of bias. Cohort studies require following patients for a sufficient length of time to allow the outcomes to happen. By then, it is inevitable that some subjects may have changed their address, some may have lost interest, moved away, died, etc. Thus, notwithstanding methodologically the present study is consistent with the second highest hierarchical level of evidence, the presence of a drop-out rate higher than 20% from the 4 year follow-up undermines the results [18] .

In the Toronto Studies the erosion of the cohort of patients during the 4-6 follow-up period was extremely high, ranging from 65% to 75%.

The present study, having been conducted in a rural village with more stable population, have got a better recall rate, with an erosion of the cohort at 4-6 years follow-up ranging from 26 to 35%. In table 12, the data about the drop-outs show better results.

Contingency table 4 shows that endodontic failure is more frequent in molars than premolars and incisors-canines ($p<0,01$), whereas mechanical failure is more frequent in premolars than molars ($p<0,05$). The presence of dental fabricated crowns increase the rate of mechanical success on premolars ($p< 0,05$), but not in molars and incisors. The group of molars with full coverage by means of prosthetic crown, though performed clinically better than those without crown, have not shown a significantly higher mechanical success on statistical point of view ($p=0,0575$). This could be explained on the basis of a short period of observation (weighted follow-up = 4 years), which had not allowed the difference becoming more manifest. This results agree with others reporting that molars and premolars endodontically treated without full coronal coverage were lost at a higher rate than fully covered teeth [19] [20] .

Considering the incidence of endodontic failures (table 9), in the present study, of the 13 endodontic failures, 10 (76% of total endodontic failures) happened in the first year post-op. One failure happened in the second year follow-up Two endodontic failures happened one at the seventh year and one other at the eighth year follow-up. In both these later failures, we could detect clinical and radiological signs of coronal leakage, whereas upon the earlier failures, ranged from 1 to 3 years follow-up, no clinical and radiological signs of coronal leakage. These results are in agreement with Orstavik [21] , who recorded that the peak of incidence of emerging apical periodontitis was within the first year follow-up, in a four year's cohort study. Of course, short observation periods may not reflect the long-term outcome of the therapy, although the probability of the emergence of a periapical lesion beyond the first year follow-up is not likely to be high. This is also in agreement with the observations of Nobuhara and Del Rio [22] , who found that the majority of apical surgeries were performed within the first 2 years after completion of endodontic therapy. Late failure could be explained due to the coronal leakage, which increases with time.

The association between coronal leakage and periapical status has been reviewed by Saunders et al.. [23]

Interesting is the result about the role of shaping and filling MB2. There was no difference in endodontic success rate between cases shaped and filled with 3 canals (78%) and cases shaped and filled with 4 canals (22%) (contingency table 6).

According to the review of Cleghorn et al. [24] , containing the most data on the canal morphology of the mesiobuccal root with a total of 8,399 teeth from 34 studies, the incidence of two canals in the mesiobuccal root was 56.8 per cent, and of one canal was 43.1 per cent in a weighted average of all reported studies. The incidence of two canals in the MB root was higher in laboratory studies (60.5 per cent) compared with clinical studies (54.7 per cent). Histological evidence, however, suggests the presence of two MB systems approaching a remarkable 100 per cent [25] .

Thus, according to the above cited studies, it is plausible to guess that in the present study at least one canal in the 50% of the upper-first-molar-group was forgotten without getting a higher failure rate. This arises a strident "cognitive dissonance" above all for who follows faithfully the Schilder's triad to the success (thorough debridement of the root canal, sterilization of the root canal, and complete obturation of the root canal) [26-27] .

An even greater dissonance occurs when we consider that the good success rate of the present study has been obtained through shaping and obturating the canal 2-4 mm short of the anatomical apex in vital cases.

The cognitive dissonance become intolerable when we consider that this high success rate was obtained through

filling most of the root canals with only cement (N2) by means of a lentulo filler. The type of root canal filling (N2 versus N2-guttapercha) had not any influence upon endodontic outcome (see contigency table 3). You are referred to the paper of Seltzer and Bender "Cognitive Dissonance in Endodontics" [27].

CONCLUSION:

The present study let to draw the following conclusions:

- the overall clinical success rate in the present study was statistically higher(p <0,001) than those of Toronto Studies
- Cohort studies in rural population allowed a better recall rate than that of big city like Toronto
- the overall clinical success rate of endodontically treated teeth had been decreasing with time, raging from 98% (1year follow-up) to 85% (10 year follow-up)
- the endodontic clinical success rate was not related to gender, age, and preoperative status of the pulp
- the molars had the higher endodontic failure rate
- the premolars had the higher mechanical failure rate
- the restoration of posterior teeth by means of prosthetic crown (full coverage), especially on premolars, increased the mechanical success rate
- The cleaning and filling of fourth canal (MB2) in upper first molars did not add any benefit to the endodontic success rate
- The most endodontic failures (76%) had been happening in the first year post-op
- Mechanical failures (n=16) are more frequent than endodontic failures (n=13). Thus more attention must to be dedicated to dentin preservation.
- The technique described in the present work allowed a low-experienced clinician conducting a general practice to obtain a success rate comparable, if not superior, to that obtained in specialist environment

Present results, nurturing and growing "cognitive dissonance" in endodontists, should help to shift from the prevailing Schilder's paradigm towards a more explicative model, as already suggested in 1965 from Seltzer and Bender. Successive transition from one paradigm to another via revolution is the usual developmental pattern of mature science[28] .

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REFERENCES:

1. Friedman S, Abitbol S, Lawrence HP (2003) Treatment outcome in endodontics: the Toronto Study—phase 1: initial treatment. J Endod 29:787–93.

2. Farzaneh M, Abitbol S, Lawrence HP, Friedman S (2004) Treatment outcome in endodontics: the Toronto Study—phase II: initial treatment. J Endod 30:302–9

3. Marquis VL, Dao T, Farzaneh M, Abitbol S, Friedman S (2006) Treatment outcome in endodontics: the Toronto Study—phase III: initial treatment. J Endod 32:299 –306

4. De Chevigny C, Dao TT, Basrani BR, Marquis V, Farzaneh M, Abitbol S, et al. (2008) Treatment outcome in endodontics: the Toronto Study. Phase IV: Initial treatment. J Endod 34:258-63.

5. Ricucci D, Russo J, Rutberg M, Burleson J A, Spanberg L (2011) A prospective cohort studies of endodontic treatments of 1369 root canals: results after 5 years. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 112:825-842

6. Friedman S. Prognosis of initial endodontic therapy (2002) Endod Topics 2:59-88

7. Telander L, Forsberg A (1966) Vital extirpation and root filling in one sitting by means of the N2 technic. A reexamination of root fillings made in 1958-1959. Sver Tandlakarforb Tidn 58(4):140-52.

8. Steup A. (2001) Radiologische Erfolgsbewertung von Wurzelkanalfullungen mit N2 im Seitenzahnbereich nach Vitalextirpation. Dissert. Univ. Aachen

9. Eriksen HM, Kirkevang LL, Petersson K (2002). Endodontic epidemiology and treatment outcome: general considerations. Endod Topics 2:1–9

10. Nair PNR. (2004) Pathogenesis of apical periodontitis and the causes of endodontic failures. Crit Rev Oral Biol Med 15(6):348-381

11. Kakeashi S, Stanley S, Stanley HR, Fitzegerald RJ (1965) The Effects of surgical exposure of dental pulps in germ-free and conventional laboratory rats. Oral Surg Oral Med Oral Pathol 20:340-9.

12. Nair PN, Henry S, Cano V, Vera J (2005) Microbial status of apical root canal system of human mandibular first molars with primary apical periodontitis after ‘‘one-visit’’ endodontic treatment. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 99:231–52.

13. Ricucci D, Siqueira JF Jr, Bate AL, Pitt Ford TR (2009) Histologic Investigation of Root Canal–treated Teeth with Apical Periodontitis: A Retrospective Study from twenty-four patients. J Endod 35:493–502

14. Broisman H, van Houte J, Krakow AA (1978) Antimicrobial effects of N2 in

vitro.Oral Surg Oral Med Oral Pathol 45(1):116-22.

15. Lai CC, Huang FM, Yang HW, Chan Y, Huang MS, Chou MY, Chang YC (2001) Antimicrobial activity of four root canal sealers against endodontic pathogens Clin Oral Investig 5(4):236-9.

16. Clark D, Khademi JA (2010) Case studies in modern molar endodontic access and directed dentin conservation. Dent Clin North Am 54:275-289.

17. Clark D, Khademi JA (2010) Modern molar endodontic access and directed dentin conservation. Dent Clin North Am 54:249-273

18. Sackett D, Haynes, RB, Guyatt GH, Tugwell P (1991) Clinical Epidemiology: a basic science of clinical medicine. 2nd ed. Boston: Little, Brown

19. Aquilino SA, Caplan DJ (2002) Relationship between crown placement and the survival of endodontically treated teeth. J Prosth Dent 87:256–63.

20. Sorensen JA, Martinoff JT (1984) Intracoronal reinforcement and coronal coverage: a study of endodontically treated teeth. J Prosthet Dent 51(6):780-4

21. Orstavik D (1996) Time-course and risk analyses of the development and healing of chronic apical periodontitis in man. Int Endod J 29:150-155

22. Nobuhara WK, Del Rio CE (1993) Incidence of periradicular pathoses in endodontic treatment failures. J Endod 19:315–8

23. Saunders WP, Saunders EM (1994) Coronal leakage as a cause of failure in root-canal therapy: a review. Endod Dent Traumatolog 10:105-108

24. Cleghorn BM, Christie WH, and Dong CCS (2006) Root and root canal morphology of the human permanent maxillary first molar: a literature review," J Endod 32:813-821

25. Kulid JC, Peters DD (1990) Incidence and configuration of canal systems in the mesiobuccal root of maxillary first and second molars, J Endod 16(7):311-7

26. Boring EG (1964) Cognitive dissonance: Its use in science. Science 145(3633):680-5

27. Seltzer S, Bender IB (1965) Cognitive dissonance in Endodontics. Oral Surg Oral Med Oral Pathol 20(4):505-16

28. Kuhn TS (1962) The Structure of Scientific Revolutions, 1st. ed., Chicago: Univ. of Chicago Press

TABLES:

Table 1. Variable distribution in the treated sample and controlled sample

	Follow-up (year)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Treated teeth (n)	626	626	602	513	439	346	265	195	134	68
Prevalent drop-outs (n)	66	93	114	121	120	106	95	74	61	33
Drop-outs rate	10%	16%	19%	23%	27%	30%	35%	37%	45%	48%
Recall rate	90%	84%	81%	77%	73%	70%	65%	63%	55%	52%
Teeth controlled (n)	560	533	488	392	319	240	170	121	73	35

Table 2. Variable distribution of prognostic factors in the treated sample

PROGNOSTIC FACTORS		**TREATED SAMPLE**	
		n	**%**
Age	>45	185	29
	≤45	441	71
Gender	Female	316	50
	Male	310	50
Tooth type	Molars	261	41
	Premolars	232	37
	Incisors-canines	133	22
Pulp vitality	Vital	503	80
	Necrotic	113	20
Root filling	N2	441	70
	N2+guttapercha	185	30
Prosthetic crown	Present	194	30
	Not present	432	70
Upper first molars	≤3 canals	61	78
	>3 canals	17	22

Table 3. Observed success and failure distribution in the controlled sample

	Follow-up (year)									
	1	2	3	4	5	6	7	8	9	10
Teeth controlled (n)	560	533	488	392	319	240	170	121	73	35
Prevalent Failures observed (n)	11	14	18	16	12	13	13	9	10	5
Incident failures observed (n)	11	3	3	1	2	2	5	4	0	0
Failure prevalence (%)	2	3	4	4	4	6	8,5	8	15	15
Overall Success rate (%)	98	97	96	96	96	94	91,5	92	85	85
Endodontic success rate (%)	98.2	98	97,7	97	98	97	96	96	92	91
Survival rate (%)	99	98	97	97	97	97	97	95	90	89

Table 4. Expected failure and success distribution in the treated sample

	Follow-up (year)									
	1	**2**	**2**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Treated teeth (n)	626	626	602	513	439	346	265	195	134	68
Overall Success rate(%)	98	97	96	96	96	94	91.5	92	85	85
Endodontic success rate (%)	98.4	98	97.7	97	98	97	96	96	92	91
Prevalent Overall Failures expected (n)	11.5	17	23	22	18	21	23	16	20	10
Prevalent Endodontic failures expected(n)	10	12.5	14	15	9	10	10.5	7	11	6

Table 5. Expected failure and success distribution in relation to the prognostic factors

Prognostic factors		Treated Sample		Expected failures	Expected success rate
		N	%	N	%
Age	>45	185	29	13.5	93
	≤45	441	71	33	93
Gender	Female	316	50	24	93
	Male	310	50	22	93
Tooth type	Molars	261	41	28	90
	Premolars	232	37	13.5	96
	Incisors-canine	133	22	4.5	96.5
Pulp vitality	Vital	503	80	15	97
	Necrotic	113	20	4.5	96
Root filling	N2	441	70	10	98
	N2+ guttapercha	185	30	9	95
Prosthetic crown	Present	194	30	4	98
	Not present	432	70	13	97
Upper first molars	≤3 canals	61	78	1,5	98.5
	>3 canals	17	22	3	83

Table 6. Distribution of failures, observed and expected, in relation to the type of teeth

Type of teeth	Failures observed (n)	Failures expected (n)	Expected failure rate (%)
Molars	19	28	**10%** (28/261)
Premolar	9	13.5	**4%**(9/232)
Incisor canines	3	4.5	**3.5 %** (4,5/133)
Total	31	46	

Table 7. Distribution of type of failures, observed and expected

Type of failure	Failures observed (n)	Failures expected (n)
Endodontic failures	13	19
Mechanical failures	16	24
Periodontal failures	2	3
Totals	31	46

Table 8. Distribution of type of expected failures in relation to the type of tooth

	Expected Endodontic failures (n)	Expected Mechanical failures (n)	Expected Periodontal failures (n)
Molars	16	4.5	3
Premolars	1.5	15	0
Incisors-canines	1.5	4.5	0

Table 9. Incidence of failures

	Year of happening of observed failures (year)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Endodontic failures (n)	10	0	1	0	0	0	1	1	0	0
Mechanical failures (n)	1	3	2	1	2	2	3	2	0	0
Periodontal failure (n)	0	0	0	0	0	0	1	1	0	0
Total failures (n)	11	3	3	1	2	2	5	4	0	0

Table 10. Success rate at 4-6 year follow-up in Toronto study and present study
Selected follow-up studies on the outcome of non-surgical root canal treatment

Study	**Follow-up (years)**	**Case observed (n)**	**Clinical success (%)**
Friedman et al. 2003 Toronto study	4-6	120	97
Farzaneh et al. 2004 Toronto study	4-6	122	95
Marquis et al. 2006 Toronto study	4-6	132	96
De Cherigny et al. 2008 Toronto study	4-6	137	94
Present study	4	374	96
Present study	6	223	94

Table 11. Success rate recalculated in Toronto study

		Recalculated Clinical success rate	
Study	**Follow-up (years)**	**Case observed (n)**	**Clinical success (%)**
Friedman et al. 2003 Toronto Study I	4-6	141	83
Farzaneh et al. 2004 Toronto Study II	4-6	153	80
Marquis et al. 2006 Toronto Study III	4-6	142	88
De Cherigny et al. 2008 Toronto Study IV	4-6	152	83
Present Study	4	374	96
Present Study	6	223	94

Table 12. Recall rate in Toronto studies and present study

		Recall rate			
Studies	**Follow-up (Years)**	**Treated teeth (n)**	**Controlled teeth (n)**	**Drop-outs (n)**	**Drop-outs rate (%)**
Friedman et al. 2003	4-6	405	141	264	65
Farzaneh et al. 2004	4-6	442	153	289	65
Marquis et al. 2006	4-6	532	142	390	73
De Cherigny et al. 2008	4-6	582	152	439	75
Ricucci et al. 2011	5	1369	816	553	40
Present study	**4**	**510**	**366**	**136**	**26**
Present Study	**6**	**346**	**215**	**123**	**35**

Contingency table 1

	Expected successes (n)	Expected failures (n)	Total (n)
Males	288	22	310
Females	292	24	316

Chi square: 0.057 p-value: 0.811 the null hypothesis is not rejected

Contingency table 2

	Expected successes (n)	Expected failures (n)	Total (n)
≤45	408	33	441
>45	171.5	13.5	185

Chi square: 0.039 p-value: 0.855 the null hypothesis is not rejected

Contingency Table 3

	Endodontic successes (n)	expected	Endodontic failures (n)	expected	Total (n)
N2 group	431		10		441
N2 guttapercha group	176		9		185

Chi-square = 2.987 p-value 0,0839 The null hypothesis is not rejected

Contingency Table 4

	Endodontic expected successes (n)	Endodontic expected failures (n)	Total (n)
Molars	245	16	261
Premolars	230.5	1.5	232

Chi-square = 9,6902 p-value 0,0019 The null hypothesis is rejected

Contingency Table 5

	Expected endodontic successes (n)	Expected endodontic failures (n)	Total (n)
Teeth with vital pulp	488	15	503
Teeth with necrotic pulp	108.5	4.5	113

Chi square: 0.106 p-value: 0.744 The null hypothesis is not rejected

Contingency Table 6

	Endodontic successes (n)	expected	Endodontic failures (n)	expected	Total (n)
Upper first molars ≤3 canals (n=61)	59.5		1.5		61
Upper first molars >3 canals (n=17)	14		3		17

Fisher's exact test p-value 0,0639 The null hypothesis is not rejected

Contingency Table 7

	Mechanical successes (n)	Mechanical Failures (n)	Total (n)
Molars	256.5	4.5	261
Premolars	217	15	232

Chi-square = 8.0165 p-value 0,0046 The hypothesis is rejected

Contingency Table 8

	Expected Mechanical successes (n)	Expected Mechanical Failures (n)	Total (n)
Teeth with crown	190	4	198
Teeth without crown	419	13	432

Chi square: 0.458 p-value: 0.5 The null hypothesis is not rejected

Contingency Table 9

	Expected Mechanical successes (n)	Expected Mechanical Failures (n)	Total (n)
Molars-premolars with crown	160.5	4.5	165
Molars-premolars without crown	307	21	328

Chi square: 3.609 p-value: 0.0575 The null hypothesis is not rejected

Contingency Table 10

	Expected Mechanical successes (n)	Expected Mechanical Failures (n)	Total (n)
premolars with crown	100.5	1.5	102
premolars without crown	117.5	13.5	131

Chi square: 8,104 p-value: 0.0044 The null hypothesis is rejected

Contingency Table 11

	successes (n)	failures (n)	Total (n)
Friedman et al. 2003 Toronto Study I	117	24	141
Farzaneh et al. 2004 Toronto Study II	122	31	153
Marquis et al. 2006 Toronto Study III	125	17	142
De Cherigny et al. 2008 Toronto Study IV	126	26	152
Present Study 4 years follow-up	359	15	374
Present Study 6 years follow-up	210	13	223

p-value < 0.0001 The null hypothesis is rejected