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ORIGINAL ARTICLE

Ten-year follow-up on adoption of endodontic technology and clinical guidelines amongst Danish general dental practitioners

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ABSTRACT

Objective: The aim of this study was to re-assess the adoption of certain endodontic technology and central treatment principles of root canal treatments as advocated by guidelines presented by the European Society of Endodontology.

Material and methods: The questionnaire included the same questions in 2003 and 2013. The general dental practitioners (GDPs) anonymously reported how frequent ('often', 'occasionally', and 'never') they used certain endodontic technology and adhered to central treatment principles. The statistical analyses were performed using Chi-squared test and Goodman–Kruskal's γ-coefficient as an association measure.

Results: The overall response rate of the 2013 group was 46.5% ($n = 531$). The frequencies of GDPs reporting often use of rubber dam, apex locator and rotary NiTi instruments were significantly higher ($p < .0001$) than in 2003, as well as reporting the use of composite resin for coronal sealing ($p < .019$). Adoption was significantly influenced by the factors gender ($p = .601$) and time since graduation ($p = .361$), and the cluster analyses revealed the neglected use of rubber dam to be associated with no established postoperative recall system.

Conclusions: After 10 years, there was a higher frequency of GDPs who had adopted certain endodontic technologies. However, progress towards high-quality root canal treatment might be obstructed as the majority of GDPs avoids consistent use of rubber dam, and routinely neglects recalls for postoperative controls of their endodontic treatments.

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Introduction

A decade ago the adoption of endodontic technologies (such as the use of NiTi instrumentation, apex locators and warm gutta-percha obturation techniques) was investigated amongst Danish general dental practitioners (GDPs) including their use of rubber dam. At that time, the diffusion of technologies in Denmark was in an early phase with adoption frequencies between 10 and 30% [1].

According to theories of diffusion of innovation [2], adoption of technologies is led by so-called front-runners or early adopters before larger adoption rates within the entire GDP population can be expected. Moreover, the adoption of one technology does not take place in isolation and a so-called technology cluster can be observed where one adoption of innovation is associated with others. In particularly, among the early Danish adopters, it was shown that frequent 'rubber dam-users' were more often associated with the frequent use of rotary instrumentation [1]. Information is sparse concerning an adoption profile among GDPs over time, and whether this cluster of technology and the association with rubber dam is a permanent pattern, perhaps reflecting a sign of an increased treatment quality.

Recent generations of dental students are brought up with the advances of endodontic technologies, whereby a natural increase of technology adoption rates is expected. However, as low frequencies of rubber dam users are reported in GDPs environments not only in Denmark but worldwide [3,4], it can be questioned whether new GDP generations actually may improve the quality and outcome of root canal treatments.

Clinical guidelines are presented both within national and international endodontic societies trying to clarify and secure the management of endodontic disease [5,6]. Therefore, knowledge on the adoption of not only technology principles and devices, but also on various central treatment principles as advocated by national and international guidelines seems warranted, and may expose some routes for future improvements of root canal treatments in general practice.

Besides the principal aspects of using rubber dam, measuring working length, instrumenting and irrigating root canals, applying inter-appointment dressings and providing

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coronal seals, also the issue of whether GDPs are routinely performing follow-up examination is sparsely documented.

The aims of this study were to: (i) re-assess the adoption of endodontic technology after ten years in a sub-population of Danish GDPs, and (ii) to measure the adoption of central treatment principles as advocated by official clinical guidelines, including follow-up routines of root canal treatments.

It was hypothesized that GDPs with a more recent undergraduate training and/or rubber-dam users have a higher technology adoption, are more likely to follow central treatment principles as advocated by national and international guidelines and also have adopted well-defined endodontic follow-up procedures, than GDPs with older undergraduate training.

Material and methods

In 2003, all GDPs from Copenhagen Dental Association (CDA), organizing both GPDs in private and public dental practices where approached with a questionnaire concerning the use of endodontic technology and this survey had a response rate of 72.4% ($n = 692$) [1]. This questionnaire was repeated in 2013 in a new group of GDPs. The 2013 study group consisted of two groups, where a random sample of 25% ($n = 278$) of the total members of CDA were approached (CDA 2013 group) and asked to participate in the study. The randomization was computerized and carried out by the Danish Dental Association. In addition, GDPs whom voluntarily attended a national one day endodontic symposium ($n = 863$) arranged by the Danish Dental Association (ES group) were approached, to test if the adopted routine was affected of interest. The questionnaire included the same adoption questions on various endodontic technologies advances as in 2003 as well as questions involving principal aspects of the root canal treatment including the use of rubber dam and follow-up routines. Three options regarding how frequent the technologies/principles were adopted in daily practice were available for the respondents; 'often', 'occasionally' and 'never'. Responses were anonymous. The CDA 2013 group and the ES group were compared in relation to gender and year of graduation. GDPs graduated since 2000 were considered to have a more recent undergraduate training, while GDPs graduated before 2000 were considered to have an older undergraduate training. The principal aspects of the root canal treatment (where a good prognosis can be expected) were based on the Quality guidelines from European Society of Endodontology [6]. The chosen principal aspects were the use of

- rubber dam,
- apex locator verified with a radiograph,
- rotary NiTi instruments,
- irrigation with sodium hypochlorite,
- inter-appointment dressing with calcium hydroxide,
- coronal sealing with composite resin or indirect restoration and
- a well-defined follow-up examination routine.

Adoption of these principles would reflect whether official guidelines were principally followed in daily practice or not.

Statistical analysis

The statistical analyses were performed in IBM SPSS Statistics version 23 (SPSS Inc., Chicago, IL). Data were analysed using Chi-squared test and Goodman–Kruskal's γ-coefficient, an association measure [1]. A positive value indicates a positive association and a negative value indicates a negative association. Data was considered significant with $p < .01$ and not $p < .05$ after controlling for false positives.

Results

There were no significant differences in regard to gender ($p = .601$) and year of graduation ($p = .361$), and there where an equal distribution of the number of root canal ($p = .351$) treatments performed between the CDA 2013 and the ES group; therefore the two groups were merged. The total response rate of the merged 2013 group was 46.5% ($n = 531$) consisting of 123 responses from the CDA 2013 group (response rate 44.2%) and 408 from the ES group (response rate 47.3%). In the merged group, 33% had a more recent undergraduate training ($n = 173$). The relative distribution of women and men from the 2013 group is displayed in Figure 1.

Comparison between Study group 2003 and 2013

After an adjustment for numerical differences between the Study group 2003 and 2013, it could be observed that the 2013 group had more dentists with a more recent graduation year ($p < .001$), as well as more females (56%, $n = 297$) compared to 2003 (50%, $n = 264$). Less root filling were completed in the 2013 group ($p < .001$).

The combined response rate was lower in 2013 than the response rate in the 2003 questionnaire. The frequencies of GDPs reporting to use rubber dam often, increased from 4 to 29% and using apex locator often from 15 to 54% ($p < .0001$) when comparing the study groups of 2003 and 2013. A significantly higher proportion was also reporting use of rotary

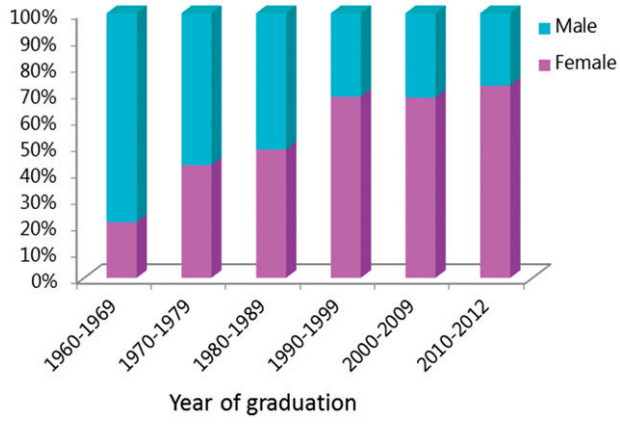

Figure 1. The distribution of men and women among the GDPs from 2013 ($n = 531$).

NiTi instruments; from 10% of the GDPs in 2003 to 69% in 2013 ($p < .0001$) (Table 1). Although the proportion of GDPs reporting use of stainless steel instrument was lower in 2013 than 2003, more than half (56%) of the responders still used stainless steel instruments (Table 1). There was also a significant decrease in the number of treatment visits for molar instrumentation. In 2013, only 6% of the GDPs used more than two appointments for instrumentation ($p < .0001$). Eighty-six percent of the dentists were in 2013 often using composite resin for coronal sealing compared to 81% in the 2003 group ($p < .019$), whereas the often use of indirect restorations had significantly decreased ($p < .001$).

Influence of time since graduation (Study group 2013)

GDPs with a more recent undergraduate training reported to more often apply a rubber dam ($\gamma = 0.182$, $p = .001$), whereas GDPs with an older undergraduate training more often only used cotton rolls to secure the working field ($\gamma = -0.212$, $p < .001$). Also, GDPs with a more recent undergraduate training reported to more often apply calcium hydroxide as inter-appointment dressing ($\gamma = 0.385$, $p < .001$), whereas GDPs with an older undergraduate training more often used camphorated mono-chlorophenol ($\gamma = -0.296$, $p < .001$). In relation to obturation, the GDPs with a more recent undergraduate training reported more often to use of single cone ($\gamma = 0.177$, $p = .001$) or gutta-percha master cone combined with hard calibrated lateral points ($\gamma = 0.167$, $p = .002$). The GDPs with an older undergraduate training used gutta-percha master cone combined with soften lateral points ($\gamma = -0.206$, $p = .001$), or warm gutta-percha with central carrier ($\gamma = -0.266$, $p < .001$).

The GDPs with an older undergraduate training reported more often to use radiography and calibrated ruler for determination of working length ($\gamma = -0.173$, $p = .005$), irrigated more often with saline ($\gamma = -0.299$, $p = .004$) and more often prepared the root canal system with stainless steel hand instruments combined with Gates–Glidden burs ($\gamma = -0.233$, $p < .001$).

The GDPs with a more recent undergraduate training reported to more often recall the patient for radiographic control of the root canal treatment 6-month post-treatment ($\gamma = 0.196$, $p = .001$).

Influence of gender (Study group 2013)

Women GDPs more often used calcium hydroxide as inter-appointment dressing ($\gamma = -0.601$, $p < .001$) and obturated the necrotic cases more often in second visit ($\gamma = -0.293$, $p = .001$) than males. Male GDPs more often used camphorated mono-chlorophenol ($\gamma = 0.262$, $p = .001$).

Table 1. GDPs reporting to often apply rubber dam and using endodontic technologies in 2003 and 2013, based on questionnaire answered by Danish dentists.

Technology	2003	2013	p value
Apex locators	15%	54%	<.0001
Rotary NiTi instruments	10%	69%	<.0001
Rubber dam	4%	29%	<.0001
Obturation of non-vital cases in third visit or later	53%	26%	<.0001
Stainless steel files	75%	56%	<.0001
Stainless steel files and Gates	42%	15%	<.0001
Warm gutta-percha	19%	10%	<.0001

p value indicates either a significant rise or drop in the adoption.

Cluster associations and clinical guidelines

GDPs reporting often to use electronic measurement devices were observed to be often users of NiTi rotary systems ($\gamma = 0.23$; $p = .002$), rubber dam ($\gamma = 0.24$; $p < .001$). GDPs who reported to often apply rubber dam also reported to often use NiTi rotary systems ($\gamma = 0.29$; $p < .001$) and warm gutta-percha techniques ($\gamma = 0.66$; $p = .003$). The adoption of NiTi rotary systems ($\gamma = 0.25$; $p < .001$) and rubber dam ($\gamma = 0.201$; $p = .001$) were associated with reports of fewer treatment sessions dedicated to instrumentation of a molar. Also the adoption of NiTi rotary systems ($\gamma = 0.20$; $p = .006$), use of electronic measurement devices ($\gamma = 0.20$; $p = .002$) and rubber dam ($\gamma = 0.32$; $p < .001$) were associated with fewer treatment sessions dedicated to vital molars. The completion of treatment was accomplished in fewer visits when canals were obturated with warm gutta-percha techniques ($\gamma = 0.65$; $p = .005$) and when rubber dam was applied ($\gamma = 0.28$; $p < .001$).

The GDPs that reported to never apply rubber dam also reported never to routinely control their endodontic treatments ($\gamma = -0.115$; $p < .0001$). The GDPs that graduated latest more often followed the aspects of clinical guidelines ($\gamma = 0.08$; $p = .009$).

Discussion

Unlike in 2003 where the adoption of new endodontic technology amongst Danish GDPs was in an early phase, the adoption of technology 10 years later confirms the theory of a delayed but significant diffusion within the larger population of potential users [2], and with a much more profound use of certain endodontic technologies as advocated by the European Society of Endodontology. In particularly, the sample of Danish GDPs had adopted technologies in relation to the technical development of instrumentation, whereas the adoption of routines focusing on infection control was still low, particularly the consistent non-use of rubber dam in daily practice.

Some limitations of the 2013 study group needs to be addressed. The total response rate to the questionnaire in 2013 was lower than in 2003, reaching a total of 531 responses in 2013 (46.5%) compared with the 692 responses in 2003 (72.4%). Thus, the representativeness of the 2013 group could be argued. The 2013 group consisted of both a random sample of CDA members and GDPs attending an endodontic symposium. It maybe that it was the most endodontically interested and motivated GDPs that participated in the symposium. However, the distribution of men and women and years since graduation were similar between these two merged groups. In contrast, gender and year of graduation profiles between 2003 and 2013 had changed significantly. Taken together, the 2013 study group represents a set-up where the most skilled and most recent educated

GDPs have responded, and in that way the results presented here could be an overestimation of adoption data as compared with the entire GDP population. However, as the proportion of GDPs using rubber dam is still rather low and clearly does not reflect basic elements of contemporary endodontics, it seems not likely that the 2013 group had a skewed distribution of GDPs containing particularly endodontically interested and motivated dentists only. On this basis, the data is judged as being credible and representative of the GDPs in Denmark.

In relation to technical equipment, the adoption of new technology has increased significantly. More GDPs are reporting the frequent use of apex locators, whereas more than two-thirds reported the frequent use of NiTi machine systems. The higher proportion of adoption of these technologies may relate to factors known to explain the diffusion rate of a certain technology, such as the 'relative advantage'. The 'relative advantage' is a factor being one of the major predictors of the diffusion rate [1,2,7] and can be exemplified by a faster completion of instrumentation in one visit [1].

In contrast, a lower adoption was noted in relation to the procedures with biological focus e.g. the adoption of rubber dam only increased from 4 to 29%. Noteworthy was the association between the GDPs who reported to never applying rubber dam, also routinely neglected to recall the patients for a postoperative recall and follow-up. The neglect to recall patients for a follow-up after a root canal treatment is in accordance to the results from a Swedish questionnaire which showed that 50% of the GDPs generally did not use a routine for postoperative recall and follow-up [8]. This could reflect a lack of focus on the biological aspects of root canal treatments and healing but may also reflect an uncertainty on how to act on persistent apical periodontitis at a root filled tooth [9]. The GDPs are not necessarily aware of their lacking endodontic skills [10,11]. Based on interviews GDPs have described a feeling of loss of control in relation to procedural steps during root canal treatments, as in an unknown reality, and they might be 'working in the dark' [12]. These feelings could possibly be explained by a general lack of endodontic skills.

There were differences in adoption between men and women in the present study. Women were more likely to apply intracanal dressings with calcium hydroxide as recommended in clinical guidelines. Also, there were differences between GDPs with an older versus a more recent undergraduate training and their adoption of endodontic technology. The GDPs seem to continue the routine and practice from what they had been taught during their education. The GDPs with an older undergraduate training seemed to continue without establishing an aseptic working field, mechanical instrumentation with stainless steel hand files, dressings with camphorated mono-chlorophenol and without a routine for a systematic postoperative recall and follow-up procedure. Again it can be stated they may live in the unknown—without knowledge about their own performance, that is the quality of the completed root fillings as well as the actual periapical status at follow-up, and they do not obtain an awareness believed to be important for changing treatment strategy [11,12].

The clinical guidelines reflect what is being taught at the universities today, and the GDPs with the more recent undergraduate training were more likely to follow the clinical guidelines in relation to using rubber dam, apex locator verified with a radiograph, rotary NiTi instruments, inter-appointment dressing with calcium hydroxide, use of composite restoration and a well-defined follow-up examination.

The aspect of non-use of rubber dam might be more complex, as this issue is not a new technology and the use of rubber dam traditionally has been taught in the undergraduate training for decades. In this study, the documentation of a cluster effect between the use of rubber dam and the technological advances, may explain an increase of rubber dam users, but it is still far from optimal.

Since the topic of adoption was introduced the interest has been growing for monitoring not only the adoption of endodontic technologies such as machine instrumentation using NiTi instruments [13], but also to explore the effect on root filling quality performed following hands-on courses [14–16].

In controlled post-education training programs where GDPs are taught the use of a specific rotary system, the vast majority of program attenders gain a significant increase in quality when assessing 'post training' root fillings both *in-vitro* [14] as well as following clinical performances [17]. The striking observation has been that the clinical outcome has not improved when comparing the performed root canal treatments before and after the training program [17], showing that the adoption of endodontic technologies *per se* cannot prevent sub-optimal root fillings [15], nor being the solely guaranty for improved treatment outcome.

Though GDPs through hands-on courses might improve the technical quality of the root filling, the improvement of the periapical status has failed to appear [14,16]. One reason among others for the lack of improvement of the periapical status, in spite of the improvement of the technical quality of the root filling, might indirectly be the lack of post-operative recalls. A follow-up visit *per se* of course will not change the quality and outcome of a poorly performed root canal treatment, but it will signal that changes of the routine might be needed. Therefore, when avoiding to perform follow-ups the GDPs are kept from becoming aware of the factual results and thus to change.

It is likely that the root canal treatment is only perceived as a failure if the patient returns with pain or other symptoms, rather than giving attention toward health effect as evaluated using radiographs [18,19]. This also becomes evident in a ten year follow-up on the status of root filled teeth in Denmark the root filling quality generally was poor and associated with periapical lesions in 42% of the teeth [20].

Within the limitation of the questionnaire study in terms of a low-response rate, it is concluded that there was a marked increase in the adoption of endodontic technologies amongst GDPs after 10 years. However, progress towards high-quality root canal treatment may still be obstructed as the majority that still avoids consistent use of rubber dam, also neglects routinely postoperative recalls and follow-ups of their endodontic treatments.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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