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The Impact of Changing from First- to Fifth-Generation Nickel-Titanium Rotaries on Root-Filling Quality in a Clinical Undergraduate Course

KEYWORDS
Root canal
Instrumentation
Dental education

SUMMARY

In this retrospective study, it was investigated whether the use of a fifth-generation rotary system (ProTaper Next) resulted in improved radiological root-filling quality compared to a first-generation counterpart (ProFile) in a controlled student course setting. Cases treated by fourth-year dental students in the 2020/2021 academic year were collected and compared to those treated in 2019/2020. Root canals in the former group were all instrumented using the ProTaper Next system and the latter using the ProFile system. All other clinical parameters were similar between the two academic years, including the time of preclinical teaching, hands-on course hours, endodontic auxiliaries, and chemicals used for treatment. After excluding patients who were not available or refused to give their informed consent to this study (n = 20) and excluding teeth with missing or poor radiographs (n = 16), the fillings in 178 roots could be assessed by two calibrated observers blinded to the system that was used. The primary outcome was the radiographic quality of the root fillings according to the five-scale modified Molander score. The secondary outcome was the number of separated rotary instruments by group. Both instrumenting systems resulted in a similar number of "excellent" root fillings (score I), 59% in the ProTaper Next group and 60% in the ProFile group, with no statistically significant difference in outcome scores between groups (probability > ChiSquare = 0.70). Furthermore, there was merely one separated instrument in the ProTaper Next group and none in the ProFile group (Fisher's exact test, p = 1.00).

Introduction

Root canal instrumentation is a decisive aspect of the so-called chemomechanical root canal debridement and therefore an important step that decides on the successful outcome of root canal treatment (Ng et al. 2008). This procedure was performed using stainless steel hand files for almost a century. Advances in metallurgy, especially since the first use of nickel-titanium rotary instruments in the late 1980s (Walia et al. 1988), have sparked a surge in instrument development over the recent decades (Haapasalo & Shen 2013). These developments have mainly aimed at simplifying the procedure for the clinician by creating instrument designs, sequences, and motorised movements that made root canal treatments more efficient (as opposed to effective). However, as has recently been demonstrated, newer systems, at least when introduced to licensed dentists, do not necessarily result in higher treatment quality or better outcomes (Dahlström et al. 2015; Jordal et al. 2022).

From a didactic point of view, the implementation of modern root canal instrumentation systems in dental student courses is also not without possible drawbacks. To prepare the students for their later profession, the focus is still on hand instrumentation, as motorised instrumenting systems are not ubiquitously available in dental offices (Thiessen et al. 2020). A further concern is that, while early-generation rotary files were standardised in taper and diameter and thus easy to combine with the ISO-normed hand instruments, newer-generation files feature variable tapers and individualised tip diameters (Haapasalo & Shen 2013). This is the reason why at our school, a first-generation rotary nickel-titanium file system was used until very recently. However, a comparison of that system with newer-generation files performed in our preclinical course changed our view (Marending et al. 2016). That study was performed in 3D-printed molar replicas and showed similar shaping outcomes for two newer-generation rotary systems compared to the first-generation system that the students knew and were taught. However, the students much preferred the newer systems over the first-generation counterpart, and the time to full canal instrumentation was almost halved (Marending et al. 2016). This prompted us to change from a first-generation to a so-called fifth-generation (Haapasalo & Shen 2013) rotary system in the 2019/2020 third-year preclinical course. That system, which is marketed under the trade name ProTaper Next (Dentsply, Ballaigues, Switzerland) features an off-centered rotation to minimise the engagement between the rotary instrument and the root canal wall (Hashem et al. 2012) and thermally processed nickel-titanium with a martensite phase component (Shim et al. 2017). Students attained better results with a fifth-generation rotary system as compared to a conventional austenitic rotary system in resin training blocks (Çelik et al. 2019). However, clinical data regarding the quality of the root canal shaping are missing.

The change in instrument systems performed in our clinical student course offered a unique opportunity to compare treatment quality attained by non-biased operators (i.e., the students) between a more traditional and a contemporary rotary system in clinics. Students received the corresponding lectures and preclinical training in their third year and performed their first root canal treatments in their first clinical course in their fourth year of study.

This controlled retrospective study aimed to assess the radiological quality of root canal treatments performed by fourth-year dental students using a fifth-generation rotary system (ProTaper Next, Dentsply) versus that obtained using a first-generation system (ProFile, Dentsply). The primary outcome that was evaluated was the radiographic quality of the root canal fillings as assessed by two calibrated observers using a standardised scoring system (Molander et al. 2007; Dahlström et al. 2015). The secondary outcome was the number of separated and non-retrieved instruments per group that could be identified on the root-filling periapical radiographs.

Materials and methods

Ethics and regulatory issues

This project complied with the Declaration of Helsinki, regulatory demands, and local law (HFG and the HFV, Swiss Federal Council). It was approved by the Ethics Commission of the Canton of Zurich (BASEC-Nr. 2021-00894). All patients treated at the University of Zurich Center of Dental Medicine are asked to sign an informed consent sheet which declares that their censored data could be used for scientific purposes. In addition, patients were asked by telephone or via e-mail whether they gave their informed consent to the current protocol, especially to the use of their personal data as described below. Patients that could not be reached or did not give their informed consent were excluded from the analysis (Fig. 1). All data used for this investigation were analysed and stored under strict observation of data protection laws.

Clinical procedures

The materials and techniques the students used for root canal treatments were similar, as were their teachers and their overall clinical set-up. The only difference was the use of the ProTaper Next (Dentsply) in 2020/2021 as opposed to the ProFile (Dentsply) system used for root canal instrumentation in 2019/2020. Before clinics, the students had received 13 lectures in endodontology and a total of 55 hours of supervised preclinical training (in their third year and at the beginning of the fourth year), as described elsewhere (Marending et al. 2016). In both academic years, 2020/2021 and 2019/2020, the step-down procedure was performed using One-Flare instruments

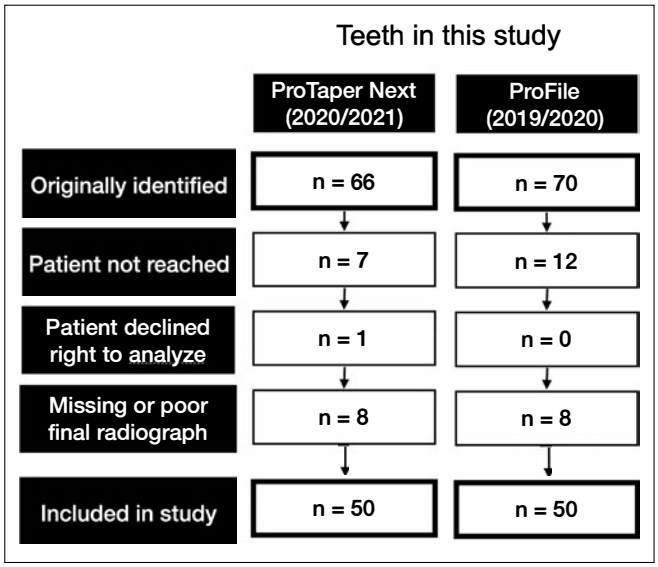

Fig. 1 Flow chart depicting the identification process of cases that were treated with ProTaper Next and ProFile. Note that the search was initially based on teeth, not patients, because it is individual teeth that get credited in the certification booklet.

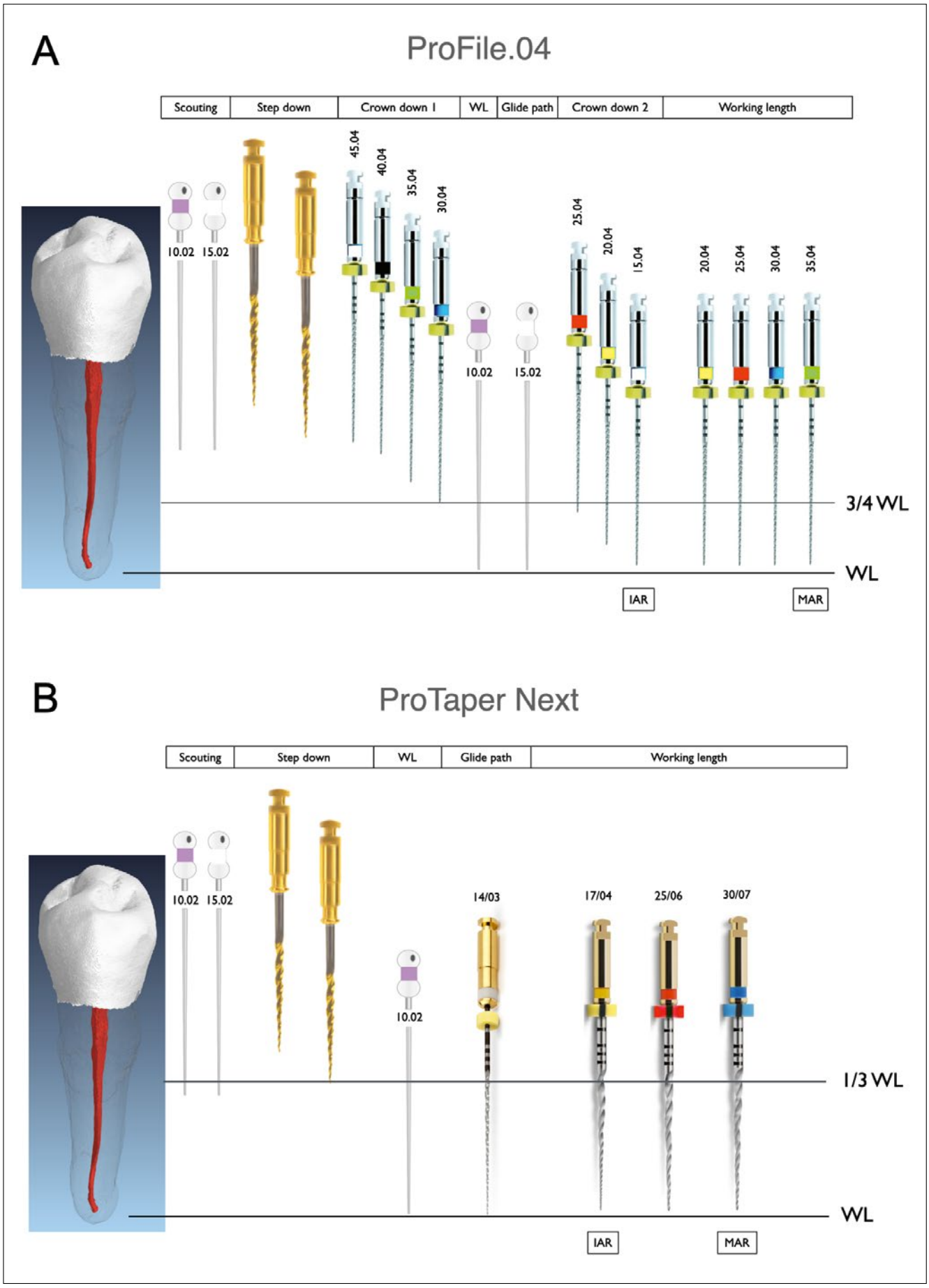

Fig. 2 Instrumenting schemes that were used to teach the students. (A) ProFile and (B) ProTaper Next. Note that both instrumenting sequences include a step-down preparation using a highly tapered rotary instrument and a glide path preparation before apical shaping.

(Coltène Micro-Mega, Besançon, France), and the glide path was prepared using either rotary instruments (One G, Coltène Micro-Mega) or small hand files (Ready Steel K-Files, Dentsply) up to size 15 (Fig. 2). Canals were instrumented to a minimal size of 35/.04 (ProFile) or 30/.07 (ProTaper Next X3). The exception to that rule was the second mesiobuccal canal (mb2) in maxillary molars, which was instrumented to a minimum size of 30/.04 (ProFile) or 25/.06 (ProTaper Next X2). The root canals were irrigated with 1% NaOCl (Hedinger, Stuttgart, Germany) containing 9% HEDP (Dual Rinse HEDP, Weinfelden, Switzerland). Canals were dried with paper points before root filling. An epoxy resin sealer (AH Plus, Dentsply) was administered on the master point. The latter was a 4%-tapered (Coltène, Altstätten, Switzerland) gutta-percha point or a proprietary gutta-percha cone (Dentsply), corresponding to the final ProFile or ProTaper Next instrument that was used to working length, respectively. Subsequently, lateral compaction was applied using finger spreaders of size A and B and the corresponding auxiliary gutta-percha points (Dentsply) to increase the amount of gutta-percha in the root fillings. A final radiograph was taken after root filling to get the respective credit for the root canal treatment by the student. Each of these working steps done by the students was supervised/controlled by a postgraduate student/resident in conservative dentistry or endodontics: caries excavation/pre-endodontic build-up, rubber dam placement, access cavity, step-down, working length determination, master apical rotary, fitting of master cones, master cone radiograph, root-filling radiograph, temporisation. Steps were signed by the responsible supervisors in a certification booklet which is used as the main document for the students to fulfill their clinical requirements and get the credit points for the clinical course in Conservative Dentistry.

Treated teeth and inclusion criteria

All the certification booklets of the students in the respective years were collected by the doctoral candidate/first author (L.M.). He checked the entries and identified all teeth and respective patients with apparently finalised root canal treatments (note: some patients received more than one root canal treatment by different students). Subsequently, he contacted all these patients to ask whether their censored radiographs could be used for this study. Teeth of patients who did not give informed consent that their censored data could be used for retrospective analysis were excluded, as were counterparts with radiographs that were missing or of insufficient quality (Fig. 1). Chart entries were used to verify that the respective systems had indeed been applied.

Assessment of root-filling quality

Two independent observers, an endodontist and teacher (M.M.) as well as an endodontic resident (K.H.), were trained and calibrated to a five-scale score (Molander et al. 2007). Inter-observer agreement was assessed by judging the filling quality in 229 roots. To that end, preselected radiographs depicting roots with root canal fillings of varying quality were used. These training radiographs were not related to this study. One week prior to the assessment observer agreement, the two observers read and discussed the concepts suggested by the original authors (Molander et al. 2007; Dahlström et al. 2015). Based on these discussions, slight modifications and specifications were made to the published scoring system: A sealer "puff" over the apex (overfilling) was judged as "correct length". Overextension of the master cone by more than 0.5 mm was judged as "defective length". When there were apparent gaps between a root canal post and the root filling, the seal was judged as "defective" (Tab. I). Roots containing fractured instrument segments were included in this analysis.

Data analysis

The individual root was used as a unit of observation. The outcome measure was the modified Molander score per root (Tab. I). In cases of two canals per root, the lesser outcome (i.e., higher score value) was tabulated. Radiographic length measurements and/or masterpoint radiographs were included for the assessment when necessary. As a secondary outcome, the number of separated files was counted per year / instrument system. To compare the root-canal filling quality scores between the two instruments, a ChiSquared test was applied. To compare the frequency of separated instruments (expected value below 5 per total treatments), Fisher's exact test was used.

Results

Identification of cases

Because of the retrospective nature and the search mode of this study, teeth treated in the fourth-year student course at the Clinic of Conservative and Preventive Dentistry, University of Zurich, were the initial unit of observation (Fig. 1). There were 44 fourth-year students enrolled in the academic year 2020/2021, and 40 in 2019/2020. According to the search criteria delineated above, 66 teeth received a complete endodontic treatment in the academic year 2020/2021 using ProTaper Next instruments versus 70 in the year 2019/2020 using ProFile instruments. A total of 16 and 20 teeth had to be excluded from these groups, respectively, because informed consent by the patients could not be obtained or because the final radiographs

Tab. I Root-filling quality score modified from Molander et al. (2007)

Score	I (best)	II	III	IV	V (poorest)
Length	+	+	–	+	–
Seal (density and homogeneity)	+	+	+	–	–
Taper	+	At least one defective	Not evaluated		
Transportation (ledge, perforation included)	–				

+ indicates that outcome parameter assessed on final periapical radiograph was within the defined treatment goals, – indicates that it was not.

Tab. II Specifications of the 50 teeth included in the analysis divided by instrumenting system

	ProTaper Next	ProFile
Patients age (y)	51 ± 15	40 ± 13
Tooth type (ft/pm/m)*	1/35/14	9/18/23
Roots excluded from analysis	1	2
Roots included in analysis	97	81

*ft = front tooth; pm = premolar; m = molar

Tab. III Modified Molander et al. (2007) scores according to instruments used (%)

	I (best)	II	III	IV	V (poorest)
ProTaper Next	57 (59%)	21 (22%)	11 (11%)	2 (2%)	6 (6%)
ProFile	49 (60%)	15 (19%)	9 (11%)	4 (5%)	4 (5%)

Probability > ChiSquare = 0.70 (Pearson)

were of insufficient quality for proper analysis. This resulted in 50 teeth per group that were included in the analysis (Fig. 1, Tab. II).

Analysis

The Kappa coefficient regarding the degree of agreement between the two observers when judging the 229 reference roots was 0.62, suggesting "substantial agreement" (Landis & Koch 1977). When judging the study roots and their root fillings, they had to exclude a total of three roots because of anatomical blurring (1) or apparently non-prepared canals (2). This resulted in 97 roots prepared with ProTaper Next instruments and 81 prepared with ProFile counterparts that could be properly assessed and were thus analysed for the study (Tab. II).

When comparing the shaping outcomes between the two systems as judged by the quality of the root fillings on the final radiographs, which was the primary outcome assessed in this study, then no statistically significant difference was found between the two rotary systems under investigation (Tab. III). The overall quality of the root fillings was good, with 81% of the roots instrumented using ProTaper Next and 79% of the counterparts instrumented using ProFile achieving a modified Molander score of I or II. In the studied roots, only one fractured ProTaper Next and no ProFile fragment was identified. Consequently, there was no statistically significant difference between the two rotary systems under investigation in the secondary outcome of this study either (Fisher's exact test, $p = 1.00$).

Discussion

This study, performed in a controlled clinical student course setting, revealed no apparent difference in the technical quality of root fillings obtained after canal instrumentation using a fifth-generation rotary system (ProTaper Next) versus a first-generation counterpart (ProFile). Moreover, there was no significant difference in the number of fractured instruments between the two systems.

This retrospective study used the unique opportunity that, despite a retrospective design, it was possible to single out the impact of using a fifth-generation rotary system over a first-generation counterpart on clinical treatment outcomes using a stringent study design (Schulz & Grimes 2002). However, there were some minor differences in tooth types and patient age between groups (Tab. II). It is unlikely that these differences could have led to a systematic error in the current investigation. Observers were calibrated, which was not done in the studies performed by the developers of the system (Molander et al. 2007; Dahlström et al. 2015). The system proved to be relatively robust with little disagreement between observers.

The radiographs assessed in this study all stem from student course patients. As Switzerland is a fee-for-service country in dentistry, i.e., there is no state-covered dental plan for the general population, the patients in these courses tend to be preselected in that they are individuals with either a lot of free time, little money, or both. Student course fees are roughly one quarter of the counterparts charged in private practices. However, the treatments patients receive in these student courses are performed under supervision by experienced dentists. The data used for this study are deriving from final periapical radiographs which are normally taken after a root canal treatment and are requested by the national quality guidelines in dentistry.

A recent randomised trial showed that the preparation sizes and tapers described in this communication should suffice to result in a good treatment outcome (Fatima et al. 2021). However, it is an inherent limitation of this study that only root-filling quality was compared and not true patient-related treatment outcomes. While it has been shown in a multitude of clinical studies that the quality of the root filling as assessed on the final radiograph does correlate with clinical outcomes (Strindberg 1956; Ng et al. 2008), this correlation is not always straightforward. As an example, healing can be obtained even when instruments are fractured, if basic treatment principles are followed and root canals are sufficiently decontaminated (Spili et al. 2005).

The quality of root fillings was high in this study, with "excellent" Molander score I reached in 59% to 60% of the roots under investigation (Tab. III). This is in line with the quality of root fillings obtained by general practitioners using ProFile in-

struments after respective lectures and training, who also reached 59% of "excellent" (score I; Molander et al. 2007) root fillings (Dahlström et al. 2015). However and despite the purported improvements in rotary instrument quality and design (Haapasalo & Shen 2013), there was no difference in root-filling quality or fractured instruments that apparently could not be retrieved between a first- and a fifth-generation rotary system under current conditions. This is in line with a more recent study on molar replicas: whilst the students preferred the newer rotary systems for their ease of use and controllability, the objective shaping outcomes were similar between ProFile and the newer systems (BioRace, FKG Dentaire, La Chaux-de-Fonds, Switzerland, and HyFlex, Coltène, Altstätten, Switzerland) (Marending et al. 2016). Other in vitro studies showed that different rotary and reciprocating systems were similar regarding their preservation of root canal anatomy (Rubio et al. 2017). Different cross-sections and geometrical file designs all maintained root canal curvature, were safe to use (Bürklein et al. 2015), and had similar transportation and centering abilities in the apical part of the canal (Kabil et al. 2021). Consequently, there may be a subjective benefit to the care provider from choosing a more modern instrumenting system, but not necessarily an objective one for the patient other than that the treatment session may be shorter. On the other hand, as shown in a most recent study, instrumenting systems with minimised instrument numbers may actually reduce root-filling quality and treatment outcomes (Jordal et al. 2022). However and as delineated above, there may be other reasons for dentists to prefer more modern root canal systems over older ones which were not investigated in this study. As shown in a recent survey (Thiessen et al. 2020), more than half of the recent graduates from Swiss dental schools work in practices that use reciprocating single-file systems for endodontic treatments. Therefore and despite any objectionable benefits on treatment outcomes, it still does appear important from a didactical standpoint to teach more modern systems with reduced file numbers to dental students. The likelihood is high that after their graduation the former dental students will be working in a clinical environment in which such systems are being used.

Acknowledgments

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Zusammenfassung

Einleitung

Rotierende Nickel-Titan-Instrumenten-Systeme zur mechanischen Wurzelkanalbehandlung haben sich seit ihrer Einführung in den 1980er-Jahren ständig verändert beziehungsweise vereinfacht. Dies wurde sowohl durch Verbesserungen im geometrischen Design der Instrumente als auch durch Neuerungen in der Nickel-Titan-Bearbeitung ermöglicht. Neuere Instrumentensysteme haben im Vergleich zu älteren eine reduzierte Anzahl von Einzelinstrumenten und sollten dabei die Kanalgeometrie besser respektieren. In dieser kontrollierten retrospektiven Studie wurde untersucht, ob die radiologische Qualität der Wurzelkanalfüllungen zunahm, wenn die Studierenden aus dem vierten Jahreskurs ein Instrumentensystem der neueren (fünften) anstatt eines der ersten Generation verwendeten.

Material und Methoden

Alle im Jahreskurs IV abgeschlossenen Wurzelkanalbehandlungen im akademischen Jahr 2020/2021 wurden über das Testatheft identifiziert und mit denjenigen aus dem akademischen Jahr 2019/2020 verglichen. Im Jahr 2020/2021 wurde exklusiv ProTaper Next zur Instrumentierung verwendet, im Jahr 2019/2020 ProFile. Alle anderen Konzepte wie Anzahl Vorlesungen, Kurszeiten, endodontische Geräte und Hilfsmittel sowie Spüllösungen und Medikamente waren in beiden Jahren dieselben. Die entsprechenden Patient/innen wurden angefragt, ob man die Röntgenbilder ihrer Behandlung anonymisiert zu Studienzwecken verwenden dürfe. Die Röntgenbilder wurden von zwei kalibrierten Beobachter/innen verblindet mittels eines Fünf-Stufen-Scores (modifiziert nach Molander et al. 2007) bezüglich der Qualität der Wurzelkanalfüllung beurteilt. Die einzelne Zahnwurzel war bei dieser Beurteilung die Beobachtungseinheit. Zudem wurde verglichen, wie viele frakturierte rotierende Feilen pro Gruppe ersichtlich waren. Die Resultate wurden mittels Chi-Quadrat und exaktem Test nach Fisher analysiert.

Resultate

Nach Ausschluss aller Patient/innen und Zähne, die nicht beurteilt werden wollten beziehungsweise konnten, blieben 97 Wurzeln, die mit ProTaper Next behandelt wurden, und 81 Wurzeln, die mit ProFile behandelt wurden, zur Analyse übrig. Mit 81% der Wurzelkanalfüllungen in der ProTaper-Next- und 79% in der ProFile-Gruppe, die einen modifizierten Molander-Score von I oder II erreichten, war deren Qualität mehrheitlich gut. Sie war nicht signifikant unterschiedlich zwischen den verwendeten Instrumentierungssystemen ($p = 0.70$). Es wurde nur ein frakturiertes ProTaper-Next- und kein entsprechendes ProFile-Instrument gefunden, womit sich also auch für diesen Untersuchungsparameter kein signifikanter Unterschied zwischen den Gruppen ergab ($p = 1.00$).

Diskussion

Die in dieser Studie erlangten Resultate zeigen auf, dass es zumindest in der kontrollierten Umgebung eines Studierendenkurses keine signifikanten Unterschiede in der radiologisch beurteilbaren Qualität der Wurzelkanalfüllungen zwischen einem neueren und einem älteren rotierenden Nickel-Titan-Instrumentierungs-System gab. Diese Beobachtung deckt sich mit anderen klinischen Studien, die zeigen, dass es wohl eher auf die richtige Anwendung der entsprechenden Systeme ankommt als auf die Systeme selbst.

Résumé

Introduction

Depuis leur introduction dans les années 1980, les systèmes d'instruments rotatifs en nickel-titane pour le traitement mécanique des canaux radiculaires ont été constamment modifiés et simplifiés. Ceci a été rendu possible par des améliorations dans la conception géométrique des instruments ainsi que par des innovations dans la fabrication du nickel-titane. Les nouveaux systèmes d'instruments ont un nombre réduit d'instruments individuels par rapport aux anciens et devraient mieux respecter la géométrie des canaux. Dans cette étude rétrospective contrôlée menée auprès d'étudiants, nous avons cherché à savoir si les

participants au quatrième cours de l'année réalisaient des obturations de canaux radiculaires de meilleure qualité lorsqu'ils utilisaient un système d'instruments plus récent (cinquième génération) plutôt qu'un système de première génération.

Matériel et méthodes

Tous les traitements radiculaires réalisés dans le cadre du cours annuel IV durant l'année académique 2020/2021 ont été identifiés via le cahier de contrôle et comparés à ceux de l'année académique 2019/2020. En 2020/2021, les étudiants ont utilisé exclusivement ProTaper Next pour l'instrumentation, en 2019/2020 ProFile. Tous les autres concepts, tels que le nombre de cours, les heures de cours, les appareils et accessoires endodontiques, ainsi que les solutions d'irrigation et les médicaments, étaient les mêmes pour les deux années. Les patients concernés ont été contactés pour obtenir l'autorisation d'utiliser les radiographies de leur traitement de manière anonyme à des fins d'étude. Les radiographies ont été évaluées en aveugle par deux observateurs calibrés à l'aide d'un score à cinq degrés (modifié selon Molander) concernant la qualité de l'obturation radiculaire. Pour cette évaluation, l'unité d'observation était la racine dentaire individuelle. En outre, le nombre de limes rotatives fracturées visibles par groupe a été comparé. Les résultats ont été analysés au moyen du chi carré et du test exact de Fisher.

Résultats

Après avoir exclu tous les patients et toutes les dents qui ne voulaient ou ne pouvaient pas être évalués, il restait 97 racines traitées avec ProTaper Next et 81 racines traitées avec ProFile à analyser. Avec 81 % des obturations canalaires dans le groupe ProTaper Next et 79 % dans le groupe ProFile ayant obtenu un score Molander modifié de I ou II, leur qualité était majoritairement bonne et ne différaient pas significativement entre les systèmes d'instrumentation utilisés ($p = 0.70$). Un seul instrument ProTaper Next a été fracturé et aucun instrument ProFile correspondant n'a été trouvé, ce qui signifie qu'il n'y avait pas non plus de différence significative entre les groupes pour ce paramètre de l'étude ($p = 1.00$).

Discussion

Les résultats obtenus dans cette étude montraient qu'il n'y avait pas de différence significative entre un système d'instrumentation rotatif en nickel-titane récent et un système plus ancien en ce qui concerne la qualité radiologique des obturations radiculaires, du moins dans l'environnement contrôlé d'un cours pour étudiants. Les résultats de cette observation concordent avec d'autres études cliniques qui montrent que cela dépend probablement plus de l'utilisation correcte des systèmes correspondants que des systèmes eux-mêmes.

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