The ability of Reciproc instruments to reach full working length without glide path preparation. A clinical retrospective study

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Background. Reciproc instruments were developed to prepare root canals without glide path preparation. As the complete preparation of root canals is associated with success in endodontic treatment we wanted to assess the ability and find predictors for Reciproc instruments to reach full working length (RFWL) in root canals of maxillary molars in primary root canal treatment (1°RCTx) and retreatment (2°RCTx) cases. **Methods.** This retrospective study evaluated 255 endodontic treatment cases of maxillary molars. 180 were 1°RCTx and 75 2°RCTx. All root canals were prepared with Reciproc instruments. The groups were compared and in a binary logistic regression model predictors for RFWL were evaluated. **Results.** A total of 923 root canals were treated with Reciproc without glide path preparation. This was possible in 885 cases (95.9%). In 1°RCTx cases 625 of 647 (96.6%) canals were RFWL and in 2°RCTx cases 260 of 276 (94.2%). In accessory canals (mb2) 94 out of 106 (88.7%) were RFWL with Reciproc in 1°RCTx and in the 2°RCTx treatment group 50 out of 52 cases (96.2%). In mesio-buccal (mb1) canals “2°RCTx” was identified as negative predictor for RFWL (OR 0.24 (CI 0.08 - 0.77)). In mb2 canals full working length was reached less often (OR 0.04 (CI 0.01 - 0.31)) if the tooth was obliterated and more often if mb2 and mb1 canals were convergent (OR 4.60 (CI 1.07 - 19.61)). **Discussion.** With Reciproc instruments the vast majority of root canals in primary treatment and retreatment cases can be prepared without glide path preparation.

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Running title: Reciproc treatment without glide path

Abstract

Background. Reciproc instruments were developed to prepare root canals without glide path preparation. As the complete preparation of root canals is associated with success in endodontic treatment we wanted to assess the ability and find predictors for Reciproc instruments to reach full working length (RFWL) in root canals of maxillary molars in primary root canal treatment (1°RCTx) and retreatment (2°RCTx) cases.

Methods. This retrospective study evaluated 255 endodontic treatment cases of maxillary molars. 180 were 1°RCTx and 75 2°RCTx. All root canals were prepared with Reciproc instruments. The groups were compared and in a binary logistic regression model predictors for RFWL were evaluated.

Results. A total of 923 root canals were treated with Reciproc without glide path preparation. This was possible in 885 cases (95.9%). In 1°RCTx cases 625 of 647 (96.6%) canals were RFWL and in 2°RCTx cases 260 of 276 (94.2%). In accessory canals (mb2) 94 out of 106 (88.7%) were RFWL with Reciproc in 1°RCTx and in the 2°RCTx treatment group 50 out of 52 cases (96.2%). In mesio-buccal (mb1) canals "2°RCTx" was identified as negative predictor for RFWL (OR 0.24 (CI 0.08 - 0.77)). In mb2 canals full working length was reached less often (OR 0.04 (CI 0.01 - 0.31)) if the tooth was obliterated and more often if mb2 and mb1 canals were convergent (OR 4.60 (CI 1.07 - 19.61)).

Discussion. With Reciproc instruments the vast majority of root canals in primary treatment and retreatment cases can be prepared without glide path preparation.

41 **Keywords:** Reciproc, glide path, root canal instrumentation, endodontic retreatment.

Introduction

The shaping of the root canal in a way that it can be disinfected completely is a big challenge in endodontic treatment and retreatment. Technical difficulties are common in negotiating and preparing root canals as naturally the anatomy of root canals has a great variability (Briseno-Marroquin et al. 2015; Vertucci 1984) and specially in maxillary molars accessory (mb2) canals are often present (Kulild & Peters 1990; Schwarze et al. 2002). These accessory canals are smaller than the main canals, often covered with dentine (Zuolo et al. 2015), obliterated and curved. Moreover also the other tooth structure is calcified frequently (Amir et al. 2001; McCabe & Dummer 2012). In retreatment cases more obstacles to root canal negotiation will arise, as old root canal filling materials have to be removed and procedural errors from initial treatment must be corrected (Gluskin et al. 2008) or cannot be corrected.

The latest developments in mechanical root canal preparation led to the introduction of reciprocating single file techniques (Bürklein et al. 2012; Yared 2008). Already rotary multiple file Nickel-Titanium (NiTi) systems enhanced the technical quality of root canal preparation (Schäfer et al. 2004). But for all rotary instruments, coronal enlargement of the canal and the preparation of a glide path was demanded (Berutti et al. 2009; West 2010). With the introduction of Reciproc instruments (VDW, Munich, Germany) the manufacturer claimed that the glide path preparation with these instruments generally is no longer mandatory (Yared 2011) even not in calcified accessory canals (Yared 2013a). That a large proportion of root canals can be prepared with Reciproc without prior glide path preparation was confirmed lately (De-Deus et al. 2013; Zuolo et al. 2015).

In retreatment cases different techniques for gutta-percha removal were advocated. This involves the application of hand files, NiTi rotary files, ultrasonic (US) instruments, heat or solvents (Ferreira et al. 2001; Wilcox et al.). Also special rotary NiTi retreatment files were developed to facilitate gutta-percha removal (Rödig et al. 2012). But these instruments have the sole purpose to efficiently remove the bulk of the old obturation materials. After that, glide path preparation remains mandatory for completion of the root canal preparation (Gluskin et al. 2008). The manufacturer of Reciproc claimed that also retreatment cases can be safely solved with these instruments as long as the procedure guidelines are followed (Yared 2013b). In several in vitro studies this claim could be confirmed (de Souza et al. 2015; Marfisi et al. 2015; Zuolo et al. 2013). But as long as in these studies just completely filled root canals were retreated, the question remains, if in clinical reality with incompletely filled canals with unexpected blockages, ledges and other obstacles the procedure remains as safe as believed. And if in these situations the waiver of the glide path preparation can be kept.

Therefore we analysed all our endodontic treatments of maxillary molars with Reciproc retrospectively. We sought to answer the question if in primary as well as in retreatment cases the technical root canal preparation can be carried out with Reciproc instruments without prior glide path preparation and reaching thereby the full working length.

Materials and Methods

For this retrospective study, patient files from the outpatient clinic of the Dental Academy of Continuing Professional Development Karlsruhe, Germany were used. Data were collected without reference to patient names and completely anonymized for evaluation. Because of the retrospective data collection, this study was a non-intervention clinical trial and did not interfere

with the psychological or physical integrity of patients. The study was conducted according to the European guidelines for good clinical practice (CPMP/ICH/135/95) and according to the Professional Code for Physicians of the Medical Council of the State of Baden-Württemberg. The Institutional Review Board of the Baden-Württemberg Medical Council reviewed the study from the ethical perspective and approved it (AZ: F-2016-031-z).

Study sample

For this clinical retrospective study all maxillary molars that were treated endodontically with Reciproc from October 2011 to October 2015 by one single operator (AB) were identified. Included were all primary root canal treatment cases (1°RCTx) and all orthograde root canal retreatment cases (2°RCTx). The age of the patients was 16 years or older. Excluded were teeth with incomplete root development and retreatment cases with previously performed apicoectomies. However, no further exclusion criteria were set regarding canal curvature, radiographically narrow canals or preoperative restauration of the tooth.

The following information was extracted from the medical records for every individual case: gender of the patient, tooth number, quantity of root canals, type of treatment (1°RCTx/2°RCTx), obliterated tooth (yes/no), reaching full working length (RFWL) or not reaching full working length (NRFWL) separately for every canal (first mesiobuccal (mb1), second mesiobuccal (mb2), distobuccal (db) and palatal (p)), a glide path was prepared (yes/no) separately for every canal, mb2 and mb1 canals convergent (yes/no), via falsa (yes/no), Forfenan retreatment case (yes/no), Reciproc instrument fracture (yes/no) and apicoectomy after orthograde (re-)treatment (yes/no).

Treatment procedures

Generally all patients were treated under local anaesthesia. All treatments were performed according to the quality guidelines of the European Society of Endodontology (2006). In every case a rubber dam was used and the complete treatment was performed with the use of a dental operating microscope (DOM) (PROergo S7, Zeiss, Jena, Germany). For all preparations a VDW.SILVER Reciproc motor (VDW) in combination with a RootZX apex locator (J. Morita Europe GmbH, Dietzenbach, Germany) or a VDW.GOLD Reciproc motor with integrated apex locator (VDW) was used with the preset program "RECIPROC ALL".

Primary root canal treatment procedures

Straight line access to the root canal orifices was established with diamond coated burs and Miller burs (both Komet Brasseler, Lemgo, Germany). All canal orifices including the accessory orifices were opened with an EndoGuide bur EG7 (SS White Burs, Inc., Lakewood, New Jersey, USA). In case of deeply calcified root canals the orifices were further prepared with a diamond coated ultrasonic tip (3E Tip on Tigon, W&H Bürmoos, Austria). After that a Reciproc R25 was used to preflare the coronal two thirds of the root canal. The Reciproc instruments were used strictly according to the manufacturers recommendations for root canal preparation without glide path preparation (Yared 2011) and according to the special recommendations for mb2 canals (Yared 2013a). During preparation the canals and pulp chamber were flooded with 3% sodium hypochlorite (NaOCl). When the R25 approximately reached two thirds of the canal length, the working length (WL) was determined using a size 10 C-Pilot file (VDW) with an apex locator. When the C-Pilot file could not reach WL, the R25 was used again to work in the canal. The procedure was repeated until WL could be determined passively with the C-Pilot file. Afterwards the complete WL was prepared with the R25 and the preparation was classified as RFWL. When the R25 did not advance further into the root canal, it was tried to actively prepare a manual

130 "glide path" with if necessary pre-bent 06, 08, 10 and 15 C-Pilot files as a matter of principle.
131 The preparation was then classified as NRFWL with the R25. The aim was in each case to obtain
132 apical patency with a 10 C-Pilot file.

133 In cases of large root canals, e.g. palatal (p) canals, an additional R40 or R50 was used for the
134 preparation of that canal. All instruments were used in one molar and were afterwards discarded.
135 If signs of deformation were visible at the instruments, they were also immediately discarded and
136 replaced by a new instrument. All small canals were further instrumented with NiTi hand files
137 (VDW) to at least ISO 35. After completed instrumentation all canals were irrigated with EDTA
138 15% and afterwards again disinfected with NaOCl 3%. All solutions were used with passive
139 ultrasonic irrigation (PUI) (Irrisafe on P5 Newtron, Acteon Germany GmbH, Mettmann,
140 Germany). After that, calcium hydroxide ($Ca(OH)_2$) was placed as root canal dressing or in case
141 of single visit treatment a gutta-percha root canal filling was placed. The detailed treatment
142 protocol was described in an earlier publication (Bartols 2013).

143 *Orthograde root canal retreatment procedures*

144 In retreatment cases the same instruments were used for access cavity preparation as in 1°RCTx
145 cases. In case of a mb2 canal, the mb1 canal was prepared first with a R25 file. In cases of hard
146 obturation materials, they were initially centre punched with a #1 Gates bur (Komet Brasseler,
147 Lemgo, Germany) for easier advancement of the R25. The R25 was used according to the
148 1°RCTx procedures. When approximately two thirds of the WL were prepared, the root canal
149 walls were cleaned in a brushing motion with the R25 to remove as much as possible of the old
150 obturation material. Then it was tried to introduce a 10 C-Pilot file to determine the working
151 length with the apex locator. If this was not possible, the R25 was used again, until passive

152 negotiation with the 10 C-Pilot file was possible. When the WL was determined, the complete
153 length was prepared with the R25 and the preparation classified as RFWL. When a glide path
154 had to be created, the preparation was classified analogue to the 1°RCTx group as NRFWL.
155 Apical patency was maintained with a 10 C-Pilot file. The cleanliness of the root canal walls was
156 inspected under high magnification in the DOM. Remnants of obturation materials were
157 removed with an Endo file K15 or K25 on the P5 Newtron (both Acteon).

158 The further treatment and disinfection protocol was the same as with 1°RCTx group. Also for
159 retreatment cases a detailed protocol was described in an earlier publication (Bartols 2013).

160 *Statistical analyses*

161 SPSS (Version 21, Win x64, IBM, Armonk, New York, USA) was used for all statistical
162 analyses. The distributions to the different treatment groups were compared with the Pearson-
163 chi-square test. The α-type error was set to 0.05.

164 Binary logistic regression analyses were performed to take potential factors that affect RFWL
165 into account simultaneously. From clinical experience and theoretical considerations we
166 hypothesized that potential factors that would affect RFWL could be the type of treatment
167 (1°RCTx vs. 2°RCTx), calcification (yes/no) and in case of mb2, if that canal was convergent
168 with mb1.

169 **Results**

170 We identified a total of 255 maxillary molars that met the inclusion criteria. 180 were primary
171 and 75 secondary treatment cases. Tooth and root canal distributions are summarized in Table 1.

We found 152 (59.6%) mb2 canals in 255 molars. 116 (75.8%) accessory canals in 153 first maxillary molars and 36 (35.3%) in 102 second maxillary molars. Overall 923 root canals were approached to be prepared without prior glide path preparation (Table 2). This was possible in 885 cases, an overall rate of 95.9%. In 1°RCTx cases 625 of 647 (96.6%) canals were RFWL and in 2°RCTx cases 260 of 276 (94.2%).

There were differences in the two treatment groups 1°RCTx and 2°RCTx in the ability of Reciproc instruments to reach full working length (Table 2). 175 out of 180 (97.2%) mb1 canals were prepared with Reciproc to full WL in 1°RCTx cases. In the 2°RCTx treatment group this was possible in 67 out of 75 cases (89.3%). The difference was statistically significant (X^2=6.81; p=0.009). In the five NRFWL 1°RCTx canals it was tried to prepare a manual glide path because the R25 did not advance further into the root canal. This was not possible and therefore two canals were prepared incompletely. In the other three canals the active glide path preparation was not possible even with pre-bent hand instruments. In these canals the use of the R25 without glide path preparation resulted in a via falsa preparation. In one of these teeth the via falsa was corrected with an apicoectomy. In one case the tooth was extracted because the patient decided against perforation repair and a surgical intervention and in the other case the patient decided to do nothing, because he was clinically symptom-free. In five out of eight canals in the 2°RCTx group the R25 did not reach full WL. Also the manual glide path preparation with pre-bent hand instruments was not possible and the canals could not be prepared completely. In the three remaining canals the preparation without glide path ended in a via falsa. These cases were treated surgically.

180 out of 180 (100.0%) db canals were fully prepared with Reciproc instruments in 1°RCTx cases. In the 2°RCTx treatment group this was possible in 69 out of 75 cases (92.0%). The

difference was statistically significant (X^2=14.75; p<0.001). In the 2°RCTx group in four out of six cases in the db canal a manual glide path preparation was not possible. One tooth had to be treated surgically. In the three remaining canals the use of R25 without glide path resulted in a via falsa. Two of these cases were treated surgically.

All 255 palatal root canals were prepared to full WL regardless of the treatment group.

90 out of 101 (89.1%) mb2 canals were completely prepared with Reciproc in 1°RCTx cases. In the 2°RCTx treatment group this was possible in 49 out of 51 cases (96.1%). The difference was not statistically significant (X^2=2.105; p=0.147). In eight cases of the eleven 1°RCTx cases NRFWL, a manual glide path preparation was tried out. By that, seven cases were solved. In one case this was not possible and the canal was ultimately classified NRFWL. In the three remaining canals a via falsa occurred with R25. In one of these teeth this was corrected with an apicoectomy. In the other cases the patients decided to do nothing, because they were clinically symptom-free. In one case a R25 file separated during mb2 preparation. The instrument was removed and the canal was prepared with a new R25 without glide path preparation. In the 2°RCTx group in one case the mb2 was prepared completely after manual glide path preparation. In the other case a R25 fractured. The fragment could not be removed. The patient was clinically symptom-free and decided to leave the instrument in situ.

In the 152 teeth with an accessory mb2 canal, 51 teeth were classified as obliterated. In twelve (23.5%) of the 51 obliterated cases R25 was NRFWL, while in only one (1.0%) of the other 101 not obliterated cases R25 was NRFWL. The difference was statistically significant (X^2=22.012; p<0.001;).

Of the 152 accessory canals 90 were classified as convergent with mb1 and 60 as not convergent. For the remaining two cases the data was missing in the medical files. In three (3.3%) of the convergent cases full WL was not reached with R25. In ten (16.7%) of the not convergent cases full WL was not reached with R25. The difference was statistically significant (X^2=8.085; p=0.004).

The 2°RCTx group included 9 Forfenan ("Russian-Red-Cement") retreatment cases. In seven of these cases R25 reached full WL. In one of the other cases a manual glide path preparation was performed unsuccessfully ending in a via falsa. In the other case a via falsa resulted from R25 preparation without glide path. The first tooth was extracted and the second tooth was treated with an apicoectomy.

During the preparation of 923 root canals in 255 teeth 2 instrument fractures (in 0.2% of the canals and in 0.7% of the teeth) and 12 via falsa preparations (in 1.3% of the canals and in 4.7% of the teeth) occurred.

The binary logistic regression models for RFWL (yes/no) are summarized in Table 3. For mb2 canals we found a significant influence to RFWL of the covariates "obliterated tooth" and "mb2 and mb1 convergent" (both $p < 0.05$). The chance was smaller for obliterated teeth to RFWL and higher for teeth with convergent mb2 and mb1 canals.

For mb1 canals there was a significant association with the covariate "type of treatment" ($p < 0.05$). In retreatment cases the chance of reaching FWL was lower than in primary treatments. Obliteration was not significant in mb1 canals.

For db canals we did not identify any covariates of significant influence. A regression model for the p canals could not be computed because all canals reached full working length.

Discussion

Our retrospective clinical study shows that a large proportion of demanding root canals was prepared without prior glide path preparation. This is true for primary root canal treatments as it is for secondary root canal treatments. In our logistic regression model we identified “convergent mb2 and mb1 canals” as positive predictor for RFWL in mb2 canals and “tooth is calcified” as negative predictor. For mb1 canals we identified “2°RCTx” as negative predictor for RFWL.

Lately, a study identified “achieving patency at the root canal terminus” as an important prognostic factor for improved healing of periapical lesions (Ng et al. 2011b) and for tooth survival (Ng et al. 2011a). Therefore it is of utmost importance, that root canals are prepared to full WL, so that proper disinfection is possible afterwards. In our study RFWL automatically included achieving patency with an ISO 10 C-Pilot file at the canal terminus. With rotary NiTi instruments glide path preparation is the prerequisite to prepare root canals to the apical canal terminus, thereby avoid instrument fractures and keep apical patency. For glide path preparation a lot of instruments are available and the procedure clearly needs a lot of patience especially in cases with obliterated root canals (West 2010) and can be substantially time consuming. Moreover, if manual preparations are performed e.g. as this is one technique for glide path preparation, dentists describe higher general physical strain and strain on their fingers than with Reciproc instruments (Bartols et al. 2016). If the glide path preparation can be avoided or waived this of course would not represent a biological objective primarily, but may reduce the effort for root canal preparation in the dimension of treatment time, number of instruments and may reduce the physical strain for the operator.

In connection with the question we sought to answer it is difficult to find an appropriate test group for comparison. At the moment there is only one machine driven instrument system (Reciproc) that was clearly developed to prepare root canals without previous glide path preparation. All rotary NiTi instrument systems need a glide path preparation to avoid instrument fractures (West 2010), that occur because of torsional stresses on the instrument (Berutti et al. 2009; de Oliveira Alves et al. 2012). From an ethical point of view it is therefore not conceivable to compare rotary instruments without glide path preparation with Reciproc in a clinical experiment head-to-head. Of course such experiments are possible in in vitro studies. But these studies do not completely cover the clinical reality with a lot more practical problems especially in retreatment cases in contrast to completely filled laboratory retreatment cases without obstacles like ledges, blockages and other problems. So we decided to choose a retrospective study design to evaluate a series of treatments that had been done anyway.

Overall we found a rate of 95.9% of root canals that were prepared with Reciproc instruments to full WL. This is a large proportion of canals that were treated without glide path preparation. An in-vitro study assessed the possibility to reach full WL with Reciproc instruments in straight and moderately curved root canals of mandibular molars which was possible in 96.4% and 90.7% respectively (De-Deus et al. 2013). So our overall rate of RFWL lies between these values. Interestingly in 98 root canals after coronal and middle third preparation of the canals a size 10 file could not reach full WL while the repeated use of the R25 led to RFWL in 67.3% of these canals. Therefore a lot of root canals were prepared completely with the R25 that otherwise would have been prepared incompletely.

But there is only little information in literature what are typical reference values for reaching full WL during root canal treatment in the clinical situation. Two connected papers (Ng et al. 2011a;

Ng et al. 2011b) contain indirectly a proportion of root canals that were assessed as patent during root canal treatment. Therefore we assume that these canals were prepared to full WL. For 1°RCTx the calculated rates from these papers are 93.5% and 94.6%, respectively, and for 2°RCTx 86.0% and 91.1% (Ng et al. 2011a; Ng et al. 2011b). But there is no information about the types of root canals treated. Our overall rates of RFWL with Reciproc instruments are about 2-3% higher as these values (1°RCTx 96.6% and 2°RCTx 94.2%) and additionally contain very demanding situations in terms of the preparation of mb2 canals of maxillary molars. Moreover, only treatments of maxillary molars are evaluated in our study, while in the studies cited, every tooth type was included. An in vitro study evaluated the R25 for RFWL in straight and moderately curved root canals in mandibular molars (De-Deus et al. 2013). For straight canals a rate of 96.4% for RFWL was found and a rate of 90.7% for moderately curved canals (De-Deus et al. 2013). In our study all (100.0%) of the palatal canals were RFWL. These canals were all straight canals or had only slight curvatures. Definitely these canals were prepared to full WL most predictably. The buccal canals can be compared with the moderately curved canals, although also severely curved canals were included in our study. 97.2% of mb1 canals and 100.0% of db canals in the 1°RCTx group were RFWL. So our clinical data reveal higher rates of RFWL than the in vitro reference values. One clinical study compared the R25 and manual glide path preparation of mb2 root canals regarding RFWL in maxillary molars (Zuolo et al. 2015). Remarkably, in only 57.5% of the canals in the manual preparation group full WL was reached, while in the R25 group this was possible in 85.6% of the canals (Zuolo et al. 2015). We found that 89.1% of the mb2 canals were RFWL with R25 in the 1°RCTx group. So our RFWL rate is about 3% higher. Most interestingly in the 2°RCTx group 96.1% of the mb2 canals were RFWL with R25 in our study.

To the best knowledge of the authors there is no clinical information available for root canal retreatments performed with Reciproc instruments with the attempt to waive glide path preparation. One clinical study describes the deformation and fracture rates of Reciproc instruments also in retreatment cases (Plotino et al. 2015). But it is not clearly stated if the retreatment cases were performed without glide path preparation. Moreover this publication contains no information about the frequency of Reciproc to reach full WL. There are only in vitro studies that evaluate the general possibility to use Reciproc instruments for endodontic retreatments (de Souza et al. 2015; Marfisi et al. 2015; Zuolo et al. 2013). All publications come to the conclusion, that Reciproc was the fastest system for retreatment. All studies found remaining filling material with all systems tested (de Souza et al. 2015; Marfisi et al. 2015; Zuolo et al. 2013). This is in concordance with our clinical experience, as it was necessary to control the cleanliness of the root canal walls under the DOM. All retreatment preparations were additionally fine finished with US instruments as described in the methods section to remove visible filling remnants.

The possibility to reach full WL with Reciproc in 2°RCTx cases was significantly lower in mb1 and db canals than for 1°RCTx cases. The logistic regression model shows, that retreatment cases have a smaller chance for RFWL in mb1 canals, even if itis taken into account that we found more obliterated cases in 2°RCTx. Additional difficulties may be pre-existent preparation faults as ledges, pre-existent via falsas that were impossible to correct and previously not properly approached mb1 canals that were instrumented in a false angle from disto-palatal instead of a straight line access. In some cases we did not find reasons for NRFWL, because it was also not possible to prepare a manual glide path. Apart from that the overall frequency of 89.3% of RFWL lies well between the 83.7% and 91.1% for 2°RCTx reported in the previously

mentioned studies (Ng et al. 2011a; Ng et al. 2011b). In the palatal root canals it was possible to reach full WL in every case. So we conclude that it is safe to prepare palatal canals without a glide path. We explain this by the fact that all of these canals were nearly straight.

In mb2 canals there was no statistical difference between the 1°RCTx and the 2°RCTx group. Interestingly the rate of RFWL was in the 1°RCTx group somewhat lower than in the 2°RCTx group. But in the 1°RCTx group in some cases it was possible to obtain full WL with Reciproc after manual glide path preparation. For mb2 preparation, our logistic regression model identified calcification of the tooth as a negative predictor for RFWL. It is remarkable, that this did not affect the other root canals. As there is no data available for the frequencies for RFWL in calcified root canals we can only indirectly guess that the substantially lower rate of RFWL with manual preparation in mb2 canals in the above mentioned study of Zuolo et al. (2015) can be partially explained by the difficult preparation of obliterated root canals. Reciproc instruments overcome this problem in the way the manufacturer claims (Yared 2013a). The positive predictor "convergent mb2 and mb1 canals" in preparation of mb2 canals for RFWL directly correlates with our clinical experience. Normally the preparation of mb2 canals is very predictable with a R25 if that canal is convergent to the mb1 canal.

In each of the treatment groups 1°RCTx and 2°RCTx one fracture of a R25 occurred. This is a very low fracture rate of overall 0.2% of the canals. Both fractures occurred in mb2 canals. Normally higher fracture rates of up to 2.4% are reported with rotary NiTi instruments (Wang et al. 2014; Wolcott et al. 2006). The rate of 0.2% in our study lies well in the range of the clinically reported fracture rates of 0.21% (Plotino et al. 2015) and 0.56% (Zuolo et al. 2015) for Reciproc. In this study we observed a rate of 4.7% of via falsas of the teeth treated. The overall rate of root perforations was reported in another study that assessed procedural errors of

endodontic treatments as 4.5% (Silva et al. 2012). The rate of root perforations in posterior maxillary teeth was reported even higher with 5.8%. Therefore the rates of our study are comparable with this study.

It was possible to prepare the vast majority of endodontic primary and retreatment cases with Reciproc to full working length without prior glide path preparation. Reciproc instruments contribute in a highly universal way to the armamentarium of the endodontic clinician. With Reciproc instruments we suggest to waive the traditional glide path preparation.

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Table 1(on next page)

Table 1. Frequencies of tooth types, root canal distributions and type of treatment.

1 Table 1. Frequencies of tooth types, root canal distributions and type of treatment.

	Quantity of teeth	Quantity of root canals per tooth						Type of treatment			
		3		4		5		1°RCTx		2°RCTx	
First maxillary molar *N* (%)	153	37	(24.2)	107	(69.9)	9	(5.9)	101	(66.0)	52	(34.0)
Second maxillary molar *N* (%)	102	66	(64.7)	36	(35.3)	0	(0.0)	79	(77.5)	23	(22.5)
Total *N*	255							180		75	

2

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Table 2(on next page)

Table 2. Root canals evaluated as reaching full working length (RFWL).

Table 2. Root canals evaluated as reaching full working length (RFWL).

Type of treatment	Tooth type	Total teeth *N*	Total root canals *N*	mb1 RFWL *N* (%)	Total mb1 RFWL %	db RFWL *N* (%)	Total db RFWL %	p RFWL *N* (%)	Total p RFWL %	Total mb2 canals *N*	mb2 RFWL *N*(%)	Total mb2 RFWL %	Total canals RFWL (%)
1°RCTx	First maxillary molar	101	389	100 (99.0)		101 (100.0)		101 (100.0)		78	67 (85.9)		369 (94.9)
	Second maxillary molar	79	258	75 (94.9)	97.2[a]	79 (100.0)	100.0[a]	79 (100.0)	100.0[a]	23	23 (100.0)	89.1[a]	256 (99.2)
2°RCTx	First maxillary molar	52	195	47 (90.4)		49 (94.2)		52 (100.0)		38	37 (97.4)		185 (94.9)
	Second maxillary molar	23	81	20 (87.0)	89.3[b]	20 (87.0)	92.0[b]	23 (100.0)	100.0[a]	13	12 (92.3)	96.1[a]	75 (92.6)
	Total **N**	255	923	242 (94.9)		249 (97.6)		255 (100.0)		152	139 (91.4)		885 (95.9)

1°RCTx - primary root canal treatment, 2°RCTx - orthograde endodontic retreatment. Values with different superscript letters indicate statistically significant differences in columns (Pearson-chi-square test, $p<0.05$).

Table 3(on next page)

Table 3. Binary logistic regression modeling for tooth related factors affecting RFWL.

Table 3. Binary logistic regression modeling for tooth related factors affecting RFWL.

Root canal	Covariate	RFWL (%)	Odds ratio (95%CI)	p-Value
mb2	**Type of treatment**			
N=150	1°RCTx	90 (89.1%)	1	
	2°RCTx	49 (96.1%)	3.27 (0.60 - 17.85)	0.172
	Obliterated tooth			
	Yes	39 (76.5%)	0.04 (0.01 - 0.31)	
	No	100 (99.0%)	1	**0.002**
	mb2 and mb1 convergent			
	Yes	87 (96.7%)	4.60 (1.07 - 19.61)	
	No	50 (83.3%)	1	**0.040**
	Nagelkerke R^2=0.392			
mb1	**Type of treatment**			
N=255	1°RCTx	175 (97.2%)	1	
	2°RCTx	67 (89.3%)	0.24 (0.08 - 0.77)	**0.016**
	Obliterated tooth			
	Yes	68 (91.9)	0.46 (0.15 - 1.45)	
	No	174 (96.1%)	1	0.187
	Nagelkerke R^2=0.091			

1°RCTx - primary root canal treatment, 2°RCTx - orthograde root canal retreatment, RFWL - reaching full working length. Bold p-values indicate statistical significance of $p<0.05$ in the logistic regression model