Assessment of damage of Endodontic Instruments with Naked Eye and Optical Instruments

Procjena oštećenja endodontskih instrumenata vizualno i optičkim pomagalima

Introduction

Endodontics is a branch of dental medicine that deals with the pathological processes of dental pulp and their consequences on the tooth and surrounding tissues. It is considered to be the only area of dentistry that is performed without a clear field of view (1). When performing endodontic procedures, the operator relies heavily on endodontic instruments made of various metal alloys. The advancements in material technology and operating techniques have enabled the use of nickel titanium (Ni-Ti) instruments driven by a machine powered by an external energy source (2). Rotary endodontic instruments were described as very flexible and with better cutting ability, when compared to manual instruments (3). However, Ni-Ti engine-driven instruments, as well as all endodontic instruments irrespective of material, are subject to fatigue, which occurs with repeated loading, thus creating micro cracks (4). Specifically, when used in curved root canals, the instruments are subjected to pressure and a tensile load that is localized at the point of curvature in the canal (5). On the other hand, in straight canals torsional failure occurs at the very top of the instrument while it is still ro-

Uvod

Endodoncija je grana dentalne medicine koja se bavi patološkim procesima zubne pulpae i njihovim posljedicama na zub i okolna tkiva. Smatra se jednim područjem stomatologije koje se gotovo u cijelosti obavlja bez jasnog vidnog polja (1). Tijekom endodontskih zahvata terapeut se u velikoj mjeri oslanja na endodontske instrumente izrađene od različitih metalnih legura. Napredak u tehnologiji materijala i operacijskim tehnikama omogućio je upotrebu nikal-titanijevih (Ni-Ti) instrumenata koje pokreće stroj koji se napaja iz vanjskog izvora energije (2). Rotacijski endodontski instrumenti oslanjaju se na vrlo fleksibilni i s boljim svojstvom rezanja u usporedbi s ručnim instrumentima (3). No, kao i svi endodontski instrumenti, opisani su kao vrlo fleksibilni i s boljim svojstvom rezanja u usporedbi s ručnim instrumentima (3). No, kao i svi endodontski instrumenti, neovisno o materijalu, Ni-Ti instrumenti s motorom podložni su znamenju da se zbog ponavljanja opterećenja stvaraju mikropukotine (4). Konkretno, kada se upotrebljavaju u zakrivljenim korijenskim kanalima, instrumenti su podvrgnuti tlaku i vlačnom opterećenju koje je lokalizirano na mjestu zakrivljenosti u kanalu (5). S druge strane, u ravnim se kanalima torzijsko oštećenje pojavljuje na samom vrhu rotirajućeg instrumenta (6). Puknuće instrumenta raz-
tating (6). Instrument fracture is a relatively common complication in endodontic procedures. The removal of a broken instrument is extremely demanding, which makes the favorable outcome of endodontic treatment harder to achieve (7). The complication of a separated instrument in a root canal often occurs due to damaged instruments; therefore, it is important to visually inspect the instrument during the shaping procedure of multirooted teeth with complicated endodontic space anatomy. Engine-driven endodontic instruments are small and the microcracks due to fatigue are even smaller. Naturally, the question arises whether the clinician is able to see such a small damage and react in time to prevent the unwanted instrument separation.

The working fields where dental procedures are performed are relatively small and at different focal lengths, hence few optical aids have gained widespread acceptance in clinical practice (8, 9). Apart from better visualization of the working field, the optical aids can be used for better inspection of the surface of the endodontic instrument and possibly detect its damage that cannot be seen with the naked eye. Another factor that has shown to significantly influence the operator’s ability to visualize objects in the working field is their eyesight, which is known to deteriorate over time (10). The aim of this study was to evaluate the accuracy of visual damage assessment of different rotating and reciprocal endodontic instruments with the naked eye and when using optical devices.

The null hypotheses are:
1. There is no difference between the age groups in estimating the Ni-Ti endodontic instruments damage.
2. There is no significant difference in damage assessment when using the naked eye or optical aids.
3. Damage to instruments is equally easy to detect regardless of the type of engine-driven endodontic instrument.

Material and methods

Examined instruments

The study was conducted at the School of Dental Medicine, University of Zagreb and approved by its Ethics Committee (approval number 05-PA-30-XXII-12/20). The study involved four dentists divided into two age groups:

I. 20-30 years, n = 2,
II. 40-50 years, n = 2

Each dentist visually assessed the existence of damage to rotating or reciprocal endodontic instruments used in shaping root canals of multirooted teeth. A total of 239 instruments from different manufacturers were estimated by each examiner. The types of instruments evaluated were: Reciproc (VDW Dental, Munich, Germany, n = 126), ProTaper Universal (Dentsply Sirona, York, Pennsylvania, USA, n = 59), Profile (Dentsply Sirona, York, Pennsylvania, USA, n = 15), One curve (Micro mega, Besancon, France, n = 13), ProTaper Next (Dentsply Sirona, York, Pennsylvania, USA, n = 12), ProTaper gold (Dentsply Sirona, York, Pennsylvania, USA, n = 2), HERO shaper (Micro mega, Besancon, France, n = 6), F360 (Komet Dental, Lemgo, Germany, n = 6). The number of times each file had been used was not recorded (6).

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corded. The examined instruments were discarded by different operators because of a perceived decrease in cutting efficiency; fracture; or any defects observed by the naked eye, such as unwinding, curving or bending. All files were cleaned by an ultrasonic cleaner and sterilized in an autoclave before inspection.

Means of examination
Before damage estimation, each examiner calibrated the eye on a new instrument. The instruments were first inspected without optical aids, with freedom of choice of the eye-to-object distance, i.e. focal length illuminated by the light from the work unit (KaVo LUX™ 540 LED, Biberach, Germany). Subsequently, the damaged instruments were selected. Instruments categorized as undamaged by the naked eye were further observed by the Keplerian loup system (EyeMag Pro S, Zeiss, Oberkochen, Germany) at a magnification of 4.3× and a distance of 400 mm from the object with illumination from the work unit. The damaged instruments noticed by the loup system were again indicated as damaged. The instruments that appeared undamaged by the loup system were further observed under an operating microscope (Zeiss Extaro 300, Oberkochen, Germany), at a magnification of 4×, a distance of 250 mm and integrated light (Figure 1). Damaged instruments were singled out in the group where the damage was detected under the operating microscope. All examiners were familiar with the use of loupes and microscopes. They were allowed to use their personal corrective glasses to compensate for visual defects while assessing instrument damage. An instrument was considered damaged if at least one examiner detected it using any method. Within the limitations of this study, instruments categorized as undamaged by all examiners and by all optical methods were not included in the statistical analysis. Damage was found in 178 instruments. Sensitivity analysis of various damage detection methods was performed on these samples.

Statistical data analysis
The sensitivity of each detection method was then evaluated using detection by each of the methods (naked eye, loupes and the microscope) by each individual evaluator as a binary variable: the differences between the variables were evaluated using detection by each of the methods (naked eye, loupes and the microscope). They were allowed to use their personal corrective glasses to compensate for visual defects while assessing instrument damage. An instrument was considered damaged if at least one examiner detected it using any method. Within the limitations of this study, instruments categorized as undamaged by all examiners and by all optical methods were not included in the statistical analysis. Damage was found in 178 instruments. Sensitivity analysis of various damage detection methods was performed on these samples.

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Statistical data analysis
The sensitivity of each detection method was then evaluated using detection by each of the methods (naked eye, loupes and the microscope) by each individual evaluator as a binary variable: the differences between the variables were then evaluated using the non-parametric McNemar test for related samples, while the differences between instrument and evaluator groups were tested using the non-parametric Mann-Whitney U test for independent samples. The significance level was set at 0.05 and all analyses were made using SPSS software (Release 20.0.0, by IBM SPSS Statistics).

Način ispitivanja
Prije procjene oštećenja svaki je ispitačka kalibrirao oko na novom instrumentu. Instrumenti su najprije pregledani bez optičkih pomagala, uz slobodan izbor udaljenosti između oka i predmeta, tj. žarišne duljine, a bili su osvijetljeni svjetlošću radne jedinice (KaVo LUX™ 540 LED, Biberach, Njemačka). Nakon toga odabrani su oštećeni instrumenti. Oni koji su okom kategorizirani kao neoštećeni, dodatno su promatrani sustavom Keplerian lupe (EyeMag Pro S, Zeiss, Oberkochen, Njemačka) u povećanju od 4,3 x i udaljenosti od 400 mm od objekta, uz osvijetljenje radne jedinice. Instrumenti koji su se pod povećalima pokazali manjkav ponovno su označeni kao oštećeni, a oni koji su se činili neoštećenima promatrani su operacijskim mikroskopom (Zeiss Extaro 300, Oberkochen, Njemačka) uz povećanje od 4 x, udaljenost od 250 mm i integriranu svjetlost (slika 1.). Oštećeni instrumenti izdvojeni su u skupinu u kojoj je oštećenje otkriveno operacijskim mikroskopom. Svi ispitački dobro su rukovali povećalima i mikroskopom. Mogli su se koristiti svojim korektivnim naočalama kako bi nadoknadili eventualne nedostatke vida tijekom procjene oštećenja instrumenta. Instrument se smatrao oštećenim ako ga je barem jedan ispitačka označio bilo kojom metodom. Unutar ograničenja ove studije instrumenti koje su svi ispitački kategorizirali kao neoštećene i poslije uporabe svih optičkih metoda, nisu bili uključeni u statističku analizu. Oštećenja su pronađena na 178 instrumentima. Na tim je uzorcima provedena analiza osjetljivosti različitih metoda otkrivanja oštećenja.

Statistička analiza podataka
Osjetljivost svake metode detekcije procijenjena je kao binarna varijabla nakon što je svaki ispitač primijenio sve metode (samo okom, povećalom i mikroskopom): različite između varijabli zatim su procijenjene neparametrijskim McNemarovim testom za zavisne uzorke, a razlike između skupina instrumenata i ispitačkih testirane su s pomoću neparametrijskog Mann-Whitneyjeva U-testa za nezavisne uzorke. Razina značajnosti postavljena je na 0,05 i sve su analize učijenjene u softveru SPSS (izdanje 20.0.0, IBM SPSS Statistics).
Results

Of the 239 instruments included in the study, 61 (25.52%) were excluded from sensitivity of damage assessment method analysis since all four examiners agreed they were undamaged. For the instruments included in the analysis of the assessment method, at least one examiner had to record damage by any one of the three optical methods used in the study: the naked eye, loupe system, and operating microscope. The total number of samples included was 178. Descriptive statistics for the two groups of examiners are given in Table 1.

When calculating the sensitivity of the damage assessment method, we considered that damage visible under the magnifying glass (the loupe) would also be visible by the naked eye. By the same concept, damage visible under the microscope would also be visible under the magnifying glass and by the naked eye. Sensitivity of the naked eye was calculated to be 49.7%, for the loupe 66.2% and for operative microscope 76.5%.

Rezultati

Od 239 instrumenata uključenih u studiju, 61 (25,52 %) isključen je iz analize osjetljivosti metode procjene oštećenja jer su se sva četiri ispitivača složila da nisu oštećeni. Za instrumente uključene u analizu metode procjene barem je jedan ispitivač morao zabilježiti oštećenje bilo kojom od triju optičkih metoda korištenih u istraživanju: samo okom, sustavom povećala i operacijskim mikroskopom. Ukupan broj obuhvaćenih uzoraka bio je 178. Opisni statistički podatci za dvije skupine ispitivača nalaze se u tablici 1.

Pri izračunavanju osjetljivosti metode procjene oštećenja smatrali smo da će oštećenja vidljiva pod povećalom (lupom) biti vidljiva i okom. Prema istom koncepciji, oštećenja vidljiva pod mikroskopom bila bi uočena i pod povećalom i samo okom. Izračunato je da je osjetljivost okom 49,7 %, za povećalo iznosi 66,2 %, a za operacijski mikroskop 76,5 %. Tri metode procjene štete značajno su se razlikovalo (p < 0,05) u osjetljivosti (tablica 2.).

Table 1

| Method                        | Age group I | Age group II | All examiners |
|-------------------------------|-------------|--------------|---------------|
| Damage not recorded           | 73 (21%)    | 94 (26%)     | 167 (23%)     |
| Damage recorded under OM      | 29 (8%)     | 45 (13%)     | 74 (10%)      |
| Damage recorded under loupe   | 47 (13%)    | 70 (20%)     | 117 (16%)     |
| Damage recorded by naked eye  | 207 (58%)   | 147 (41%)    | 354 (50%)     |
| Total                         | 356 (100%)  | 356 (100%)   | 712 (100%)    |

| Method                        | Sensitivity | CI 95%       |
|-------------------------------|-------------|--------------|
| Naked eye                     | 49.7%       | 46.1–53.4    |
| Loupe                         | 66.2%       | 62.5–69.6    |
| Operating microscope          | 76.5%       | 73.3–79.6    |
| Invisible                     | 23.5%       | 20.4–26.7    |
| Total                         | 100.0%      |              |

* The methods with a different number are significantly different by sensitivity from each other, p<0.001, McNemar test for related samples

Table 3

| Method  | Sensitivity Age group I | Sensitivity Age group II | P value* |
|---------|-------------------------|--------------------------|----------|
| Naked eye | 58.1%                   | 41.3%                    | < 0.001  |
| Loupe    | 71.3%                   | 61.0%                    | 0.003    |
| Microscope | 79.5%                  | 73.6%                    | 0.063    |
| Invisible | 20.5%                   | 26.4%                    | 0.063    |
| Total    | 100.0%                  | 100.0%                   |          |

* Mann-Whitney U-test
The three methods of damage assessment differed significantly \( (p < 0.05) \) in sensitivity (Table 2).

In order to compare the sensitivity between the younger and older examiners, it was found that the younger examiners were more sensitive to noticing damage by the naked eye and by the loupe (Table 3).

A further analysis of the instruments was divided into groups according to the type of wire, i.e. heat treatment procedures, to which Ni-Ti alloys had been subjected. The conventional wires \( (n = 72) \), M-wire \( (n = 91) \) and C-wire \( (n = 13) \) were included for further analysis. The gold heat treated group was excluded from further analysis due to a small sample size \( (n = 2) \).

It was shown that a significantly greater percentage of damage to conventional instruments was visible by any optical method compared to the M-wire instruments (Table 4).

Similar results were obtained when ProTaper Universal and Reciproc instruments were compared, as representatives of the two groups. It was again shown that sensitivity to damage assessment was significantly greater in the case of Pro Taper instruments by all methods \( (p < 0.05) \) (Table 5).

**Discussion**

The present study determined the sensitivity of the naked eye, a loupe and an operating microscope in assessing the damage to engine-driven endodontic instruments. Generally, there were three principal advantages of magnifying loupes: compensation for presbyopia, ergonomic and optical benefits (11). A study by Eichenberger et al. (8) found that the visual acuity can be improved by 250–961% by the use of magnification devices, independent of age and natural visual acuity. This hypothesis was consistent with our experiments. The sensitivity of the microscope was greater compared with the ing microscope 76.5%. The three methods of damage assessment differed significantly \( (p < 0.05) \) in sensitivity (Table 2).

**Rasprava**

U ovom istraživanju proučavala se osjetljivost oka, povećala i operacijskog mikroskopa u procjeni oštećenja strojnih endodontskih instrumenata. Općenito su tri glavne prednosti postupaka povećanja kompenzacija kratkovidnosti te ergonomskie i optičke prednosti (11). Istraživanjem Eichenbergera i suradnika (8) utvrđeno je da se oštrina vida može poboljšati za 250 do 961 % upotrebom uređaja za povećanje, neovisno o dobi i prirodnim oštrim vida. Ta je hipoteza u skladu s našim eksperimentom. Osjetljivost mikroskopa veća je od povećala čak i pri usporedivim čimbenicima povećanja. To se može objasniti-
loupes even at comparable magnification factors. This can be explained by a greater angle between the two optical beams and the static position of the microscope, offsetting any disturbances caused by head movements (8, 12).

We focused on the sensitivity of the eye in evaluating any possible damage to endodontic files that had previously been used in endodontic treatment. We have shown that sensitivity of the eye alone is 49.7%, thus showing that the eye alone detects, on average, about half of damage. Therefore, the other half of it remains unrevealed unless optical aids are used. These findings corroborate the study of Stapan (13). It has been observed that fracture of Ni-Ti files can occur with little or no visible evidence of accompanying plastic deformation or, in other words, permanent change of its shape (14, 15). Such a situation could possibly lead to repeated use of a damaged instrument, thus increasing the risk of instrument separation when endodontic procedures are performed.

Some examiners had better visual acuity by their naked eye. This could be due to the examiner’s age (10). The first group was made of younger assessors. They were able to notice damage by their naked eye with significantly improved astuteness. On the other hand, the older group of examiners benefited more from the use of optical aids. Consequently, the second null-hypothesis has been rejected.

Instrument observation conditions are another important factor. Our experiments were performed during the day and the light from the work unit was used.

As mentioned, the sensitivity of the magnifying glass measurement was 66.2%, while the sensitivity of the microscope measurement was 76.5%. The difference between these methods was statistically significant ($p < 0.05$), between the sensitivity of the measurement of the eye, magnifying glass and microscope. It is questionable whether this is clinically relevant since it is subjective: it depends on the values considered to be “good enough”, determined by the level of risk associated with a false negative result. Within the limitations of this study, we have obtained no false positive results.

As far as the type of alloy is concerned, the Ni-Ti alloy was introduced for instrumentation in curved canals, mostly because of their shape memory property associated with temperature changes (16). In addition, they increase the speed of the endodontic procedures, allowing the dentist to invest more time into the irrigation (17). The most visible damages were found on M-wires. The difference was statistically significant ($p < 0.05$) for conventional materials compared to M-wire, while the differences between the C-wire and conventional materials as well as the C-wire and M-wire were not statistically significant. It should be noted that the number of samples for the C-wire was relatively small ($n = 52$), which affects the power of testing, but the values for the C-wire are between those of the M-wire and conventional ones. The difference by each method is statistically significant between the two most commonly used instruments in the experiment, Protaper Universal and Reciproc, which does not mean that one material is more prone to damage than the other. In other words, a higher percentage of damage to the Protaper Universal instrument was optically noticeable compared to Reciproc.
Apart from the many benefits of using an operating microscope in endodontics, including visual and ergonomic enhancement (18), within the limitations of this study, the results suggest that it is the superior option for therapists to assess an endodontic file for damage. This could reduce the frequency of instrument separation inside the root canal by damaged files. Nonetheless, unexpectedly, there are hardly any studies to address this important aspect of endodontic therapy, possibly due to the relatively recent introduction of optical aids to dentistry (19). Further research is therefore needed.

Conclusion
It can be concluded that there is a significant difference between age groups in the estimation of instrument damage with younger examiners being superior to notice damage by the naked eye. Furthermore, there was a noteworthy difference in damage assessment by the naked eye compared to the assessment by optical aids. Finally, significant differences in the ease of identifying damage between the different types of engine-driven endodontic instruments were found. However, this does not necessarily imply that one type of instrument is more prone to damage than the other.

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Conflict of interest
The authors declare no conflict of interest.
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