Influence of several factors on the success or failure of removal of fractured instruments from the root canal

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Abstract - The influence of several factors on the success rate of removal procedures of fractured endodontic instruments was evaluated postoperatively. In 105 teeth with 113 fragments removal attempts were undertaken using a wide range of techniques and instruments. All cases were analyzed with special regard to the following factors: type of tooth and root canal, site of fragment in relation to root canal curvature, length of fragment, and type of fractured instrument. Success of treatment was defined as removal or complete bypassing of the fragment. Of 82 instruments in molars (maxillary: 32, mandibular: 50), 56 were removed or bypassed (max.: 26, mand.: 30). Of 16 fragments in premolars (max.: 12, mand.: 4), 8 could be removed or bypassed (max.: 6, mand.: 2). Of 14 fragments in canines and incisors (max.: 7, mand.: 7), 13 could be removed completely (max.: 6, mand.: 7). When the fragment was localized before the curvature 2 of 18 cases failed, when localized inside the curvature 13 of 31 cases failed and when localized beyond the curvature 15 of 33 cases failed. Anatomical factors favorable for removal were: straight canals, incisors and canines, localization before the curvature, length of fragment more than 5 mm, localization in the coronal or mesial third of the root canal, reamer or lentulo spirales. In molars removal procedures were most successful in the palatal canals of maxillary molars.

Fracture of root canal instruments is one of the most troublesome incidents in endodontic therapy. "The dentist who has not fractured the tip of a reamer, file or broach has not treated many root canals ... Who has not felt the pang, the anguish, the mortification caused by the breaking of an instrument? That moment of remorse lives on for days until it is faded out by time," noted Grossman (1).

Evaluations of endodontic recall radiographs indicated that the frequency of remaining fragments ranges between 2% and 6% of the cases investigated (2–8). According to Grossman (9) and Crump & Natkin (10) the prognosis of teeth with remaining fragM. Hülsmann, I. Schinkel

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ments mainly depends on the preoperative condition of the periapical tissue. Prognosis was favorable in vital pulp extirpation cases. In teeth in which a periapical lesion could already be diagnosed preoperatively, healing occurred in only about half of the cases. However, in almost all cases where no pathological changes were recognized before treatment, the teeth remained without symptoms in spite of incomplete instrumentation and obturation. Ingle & Beveridge (11) have shown that less than 1% of endodontic failures result from broken instruments.

The orthograde removal of broken instruments in most cases is very difficult and often hopeless. Never-

theless, an attempt to remove these fragments should be undertaken in every case. Intentionally leaving a fragment in the root canal may only be considered when nonsurgical removal has been attempted without success. No standardized procedure for successful removal even in difficult cases exists, although a number of different techniques and devices have been described in the literature (12, 13), among them the Masserann-Kit (14, 15), ultrasonics (16-20), and the Canal-Finder-System (21-23). Although the removal of fractured instruments sometimes is a rather difficult and time-consuming procedure the success rate has been reported as 55% to 79% (12). Three studies from the early 1970s report on the successful use of the Masserann-Kit (6, 14, 16). In vitro studies using ultrasonics show 79% and 68% success, whereas in vivo 67% of the fragments could be removed (20). The use of the Canal-Finder-System resulted in 59% of the fragments being removed or bypassed in an in vitro study, and 58% in vivo (22). But technical equipment should not be considered the only factor influencing success or failure of removal procedures. The skill and experience of the operator as well as anatomical factors (root canal curvature, root canal diameter) may be even more important factors.

Therefore, it was the aim of this retrospective study to evaluate the influence of several factors (type of tooth and root canal, length of fragment, site of fragment with regard to root canal curvature, type of fractured instrument) on the success or failure of attempts to remove fractured instruments from the root canal.

Material and methods

In 105 teeth in 105 patients with 113 fragments removal attempts were undertaken using a wide range of techniques and instruments. The following devices and techniques were most frequently used: Canal-Finder-System (SET, Marseille, France), Ultrasonics (Piezon Master 400, EMS, Munich, Germany), hand instruments: reamers for bypassing and Hedstroem files for removal (braiding technique), and chelating agents (Calcinase, Lege artis, Dettenhausen, Germany). In most cases more than one technique and device were used until the fragment was removed or bypassed or the removal attempt was stopped. All patients were treated by the same dentist (MH).

The patients with fractured instruments were discovered during routine initial radiographic examinations in the different departments of the dental clinics during the students' or assistant teachers' clinical treatment courses, or were referred by general practitioners to the Department of Operative Dentistry.

All cases were analyzed with special regard to the following factors: type of tooth and root canal, degree of root canal curvature, site of fragment in relation to the root canal curvature, radiographic length of

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fragment, and type of fractured instrument. The degree of root canal curvature was determined using the method described by Schneider (24). Procedural accidents such as additional instrument fractures or root perforations were evaluated by control of the treatment protocols or the radiographs. All radiographs were evaluated with an X-ray viewer (Microbox, Fa. Welp, Bad Nauheim, Germany) under a $10 \times magnification$.

Success of treatment was defined as removal or complete bypassing of the fragment. Due to the small number of cases in the subgroups and the relatively large number of variables no statistical analysis could be undertaken.

Results

Overall success/failure rate

The overall success rate was 68.1%: 55 fragments (48.7%) could be removed completely and 22 (19.4%)



Fig. 1. The fragment in the middle part of the curved mesio-lingual root canal of this mandibular molar could be bypassed completely. The case was rated a success.



Fig. 2. The attempt to remove this fragment resulted in a root perforation as the tip of the instrument was directed to the root outside by the top of the fragment. The case was rated a failure.

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Table 1. Summary of results of removal attempts by type of tooth and root canal

			Bypassed	Success		Failure		
	п	Removed		п	%	п	%	
Maxillary teeth	52	29	9	38	73	14	27	
Molar								
Palatal canal	5	3		3	60	2	4023	
Buccal canals	28	17	6	23	82	5	18	
Premolar	12	3	3	6	50	6	50	
Canine/incisor	7	6		6	86	1	14	
Mandibular teeth	61	25	14	39	64	22	36	
Molar								
Distal canal	12	6	2	8	67	4	33	
Mesial canals	38	11	11	22	58	16	42	
Premolar	4	1	1	2	50	2	50	
Canine/incisor	7	7		7	100			
Total	113	55 (48.7%)	22 (19.4%)	77	68.1	36	31.9	

could be bypassed completely (Fig. 1) so that they were embedded in gutta-percha. In 36 cases (31.8%) removal procedures failed: in 13 of these failures (11.5%) the removal procedures ended with root per-



Fig. 3a. Small fragment localized in the apical part of the distal canal of a lower molar.

Fig. 3b. The fragment could be removed completely.

forations (Fig. 2). Additional instrument fractures were not observed (Table 1). The success rate was slightly higher in maxillary (73%) than in mandibular teeth (64%).

Type of tooth and root canal

The results of removal attempts with regard to the type of teeth and of the root canal in which the instruments had fractured are summarized in Table 1. The majority of the fractures had occurred in molars; the most frequently involved root canals were the mesial canals of mandibular molars followed by buccal canals of maxillary molars. The lowest success rates were found in maxillary (50%) and mandibular premolars (50%).

Site of fragment

All fragments from the coronal third of the root canal (n=5) could be removed completely. When the fragment was localized in the middle third (n=44) or in the apical third (n=44), the success rates were 68% and 59%, respectively (Fig. 3 a-b). Long fragments extending over the complete root canal (n=7) could all be removed. From 6 fragments extending beyond the apical constriction 3 were removed (Table 2).

Localization of fragment with regard to curvature

Most of the fractured instruments were localized inside (n=31) or beyond (n=33) the root canal curvature. In these groups the success rates (58% and 52%, respectively) were lower than in straight root canals with a success rate of 82%. The highest success rate was found when the instrument had fractured before the curvature (Table 3).

Table 2. Success and failure of removal attempts by site of fragment

				Success			
	n	Removed	Bypassed	п	%	Failure	
Coronal third	5	5	0	5	100	0	
Middle third	44	17	13	30	68	14	
Apical third	44	19	7	26	59	18	
Beyond apex	7	3	0	3	43	4	
Complete canal	7	7	0	7	100	0	
Coronal and middle	2	2	0	2	100	0	
Middle and apical	4	2	2	4	100	0	
Total	113	55	22	77	68	36	

Table 3. Success and failure of removal attempts by relation between fragment and root canal curvature

Relation to				Suc		
curvature	п	Removed	Bypassed	n	%	Failure
Before	18	10	6	16	89	2
Inside	31	14	4	18	58	13
Beyond	33	12	5	17	52	16
Straight	22	15	3	18	82	4
Before/inside	3	2	1	3	100	0
Inside/beyond	6	2	3	5	83	1
Total	113	55	22	77	68	36

Table 4. Success and failure of removal attempts by degree of root canal curvature

				Suc	cess	
Curvature (°)	п	Removed	Bypassed	п	%	Failure
0–10°	38	24	4	28	74	10
11-20°	33	15	7	22	67	11
21–30°	28	11	8	19	68	9
31–40°	11	3	3	6	55	5
41–50°	2	1		1	50	1
51–60°						
61–70°						
71–80°	1	1		1	100	
Total	113	55	22	77	68	36

Degree of curvature

The results concerning the degree of curvature of the involved teeth are summarized in Table 4. The success rate was highest in roots with a curvature between 0° and 10° (74%) and only slightly worse in root canals with curvatures from $11^{\circ}-20^{\circ}$ and $21^{\circ}-30^{\circ}$ (67% and 68%, respectively). The success rate was lower in teeth with higher degrees of curvature.

Type of fractured instrument

The results concerning the type of the fractured instruments are presented in Table 5. Some of the fragments could not be identified due to deformation, loss of fragment, unclear radiographic feature, or failure in removal. Most of the fractured instruments were definitely or probably Hedstroem files (n=51); 67% could be removed or bypassed. Lentulos were involved in 14 cases, 13 (93%) of these could be removed completely (Fig. 4 a-b). Reamer-type instruments (n=17) were treated successfully in 76% of the cases. The remaining identifiable fragments were Gates-Glidden burs (n=5), NiTi files (n=3), and an ultrasonic file (n=1).

Length of fragment

The results of removal attempts with regard to the length of the fragment are summarized in Table 6. In subgroup A, including all fragments shorter than 5 mm, 32 of 78 fragments could be removed and an additional 16 bypassed. The success rate was 62%. In subgroup B, including all fragments 5–10 mm length (n=24) 13 fragments were removed completely and an additional 5 bypassed. The success rate was 79%. In subgroup C, including all fragments between 10.5 and 15 mm (n=10), 9 fragments could be removed; the success rate was 89% (Fig. 5).

Discussion

It is widely acknowledged that conservative retreatment of cases of previously failed endodontic therapy produces good results. Success rates between 65% and 84% have been reported in several investigations (25–29). The prerequisite for these success rates is complete removal of the obturation material

Table 5. Influence of type of fractured instrument on success and failure of removal attempts

Type of instrument	п	Removed	Bypassed	Success	Failure
Hedstroem file	46	19	11	30	16
Probably Hedstroem file	4	2	1	3	1
Lentulo	12	12		12	
Probably Lentulo	2	1		1	1
Reamer	14	11	2	13	1
Probably Reamer	4		1	1	3
Spreader	3			0	3
Probably Spreader	2	1		1	1
Gates-Glidden	5	2	2	4	1
Lightspeed	2	1		1	1
Profile	1	1		1	
Ultrasonic file	1	1		1	
Not identified	17	4	5	9	8
Total	113	55	22	77	36



Fig. 4a. Lentulo fractured inside curvature of first maxillary molar. Fig. 4b. The lentulo could be removed completely.

and proper cleansing and disinfection of the root canal system. Whereas semisolid filling materials in most cases may be removed with hand instruments and the use of softening agents such as chloroform, xylene or halothane, the removal of solid metal objects may be more difficult (12). This is true especially for the removal of inadvertedly fractured instruments. Instrument fracture occurs during preparation of the root canal when the root canal still is rather narrow and not finally flared, so in many cases there is hardly any space to bypass the fragment. Some instruments, for example Hedstroem files, tend to fracture when used in an excessively rotational movement. Once "screwed" into the root dentin it is very difficult and time-consuming, sometimes even hopeless, to loosen and retrieve these fragments. Meanwhile there are several clinical reports on different devices and techniques for the treatment of such situations (for review see 12, 13), but only very few data exist on the success rates of such devices and techniques.

On the other hand it should be obvious that special techniques and devices are not the only factors that influence the success or failure of removal attempts. The type and length of the fractured instrument as well as anatomical factors may be at least equally important. In the present study lentulo spirales and reamers were most frequently removed, probably due to their shape (lentulos) and their fracture mode (reamers), whereas Hedstroem files showed a lower success rate. This may be because these instruments often fracture when they are screwed in a rotational motion into the root dentin. This results in close contact with the root canal wall, leaving little or no space for bypassing, whereas reamers with a triangular, rectangular or rhomboid cross-section may leave at least a minimal space for bypassing. Lentulo spirales in many cases may be instrumented via the empty center of the instrument and thus easily grasped.

Concerning the length of the fragments long fragments seemed easier to remove than short fragments. The success rate was higher when the fragment was longer than 5 mm. Again it may be presumed that the longer fragments were engaged into the root dentin at their tips and thus provided at least some space for bypassing in the coronal part, thus facilitating loosening, for example, by ultrasonics.

The success of removal attempts seemed also to be related to the type of root canal. In canines with large root canals all 14 fragments could be removed com-

Table 6. Success and failure of removal attempts by length of fragment

l enath					Suc	cess	
Group	(mm)	п	Removed	Bypassed	n	%	Failure
A	1.5	3	1	1	2	67	1
	2	9	4	3	7	78	2
	2.5	8	3	2	5	63	3
	3	12	5	2	7	58	5
	3.5	17	3	6	9	53	8
	4	18	9	2	11	61	7
	4.5	4	2		2	50	2
	5	7	5		5	71	2
	<5	78	32	16	48	62	30
В	5.5	2	2		2	100	
	6	11	4	4	8	73	3
	6.5	1			1	0	1
	7	5	3	1	4	90	1
	8	2	2		2	100	
	9	1		1	1	100	
	10	2	2		2	100	
	5.5–10	24	13	6	19	79	5
c	11	2	2		2	100	
	11.5	2	2		2	100	
	12	1	1		1	100	
	13	1	1		1	100	
	14	2	1		1	50	1
	15	1	1		1	100	
	11-15	9	8		8	89	1
	17	1	1		1	100	
	18	1	1		1	100	
	Total	113	55	22	77	68.1	36

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Fig. 5. Although localized in a radiographically straight root canal this small fragment (arrow) in the middle of a second premolar could be neither bypassed nor removed.

pletely. In distal canals of mandibular molars and palatal canals of maxillary molars the success rates were 67% and 60%, respectively, which probably was due to the shape of the canals, which in most cases is oval or irregular, at least in the coronal and middle sections. In mesial canals of mandibular molars, although mostly moderately or even severely curved, the isthmus between the mesio-buccal and mesio-lingual canal in some cases allowed bypassing of the fragment, resulting in a success rate of 58% (Fig. 6 ab). Most difficult to treat were premolars, mandibular as well as maxillary, which in most cases showed rather narrow root canals.

Concerning root canal curvature it was no surprise that removal success was higher in straight or only moderately curved canals, although it should be kept in mind that radiographs only allow two-dimensional analysis of three-dimensional curvatures. Fragments localized apically to the curvature showed a relatively low success rate compared to fragments localized coronally or inside the curvature.

During the removal attempts of this study 12 root perforations occurred (10.6%), 7 of these in the difficult mesial canals of mandibular molars. In most of

these cases the tip of the instrument used for bypassing probably was directed to the root canal wall by the top of the broken instrument (Fig. 2). No additional instrument fractures or other procedural incidents occurred.

Finally it should be stressed that in all cases of instrument fracture several factors influenced the treatment outcome so that no definite preoperative prognosis on the probability of successful retrieval could be made. Nevertheless, certain factors concerning the site of the fragment and the type of root canal might give valuable hints, which are helpful for informing the patient preoperatively on the presumed treatment outcome and possible treatment risks.

The influence of the removal technique could not be evaluated as in most cases a variety of techniques and devices had to be used until removal or bypassing was achieved or failure became evident. Nevertheless, the techniques and devices used for removal as well as the operator's skill, experience and level of fatigue had an important influence on the treatment outcome.



Fig. 6a. Fractured instrument in the curved root canal of a mandibular molar.

Fig. 6b. The fragment was bypassed via the isthmus between the mesio-lingual and mesio-buccal root canals and could finally be removed by ultrasonics. The radiograph indicates a massive loss of dentin.

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In the present investigation the following devices and techniques were most frequently used: Canal-Finder-System, ultrasonics, hand instruments: reamers for bypassing and Hedstroem files for removal (braiding technique), and chelating agents. Nevertheless, several other devices and techniques have been described in the literature (12–20, 30–33). With very few exceptions (6, 14, 16, 20, 22) there unfortunately are no data on the success rates of fragment removal for the different techniques or devices.

Although no statistical analysis was performed in the present study because of the relatively small number of cases and the relatively large number of variables, there seemed to be several factors influencing the outcome of attempts to remove broken instruments from the root canal system. The success rate was higher:

- In maxillary teeth (73%) than in mandibular teeth (64%)
- When the fragment extended into the coronal third of the root canal
- When the instrument had separated before the root canal curvature
- For fragments longer than 5 mm
- For reamer-type instruments and lentulo spirales than for Hedstroem file type instruments.

Anatomical factors favorable for removal were: straight canals, single-rooted teeth, localization before the curvature, localization in the coronal or mesial third of the root canal.

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