Periodontal healing after replantation of traumatically avulsed human teeth

Assessment by mobility testing and radiography

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The purpose of this study was to examine tooth mobility changes after replantation of avulsed permanent teeth and to correlate these data with radiographic and clinical findings. The material consisted of 35 patients in whom 40 accidentally avulsed permanent incisors were replanted. Mobility testing was performed with a modified macroperiodontometer. Combined clinical, radiographic and mobility findings indicated that healing after replantation could be divided into the following modalities: 1. *Normal healing* with slightly increased or normal mobility values and no radiographic sign of progressive root resorption. 2. *Permanent replacement resorption* with lowered mobility values and radiographic sign of replacement resorption. Decreased mobility values indicate that ankylosis was usually evident 5 weeks after replantation. At the same time, it was possible to diagnose the ankylosis by the percussion test. The radiographic examination first revealed ankylosis 8 weeks after replantation. 3. *Transient replacement resorption* (not previously described) with lowered mobility values which later became normal. Radiographic signs of a transient replacement resorption were present in some cases. 4. *Inflammatory resorption* with increased mobility values and radiographic sign of inflammatory root resorption. Mobility values tended to become normal when inflammation subsided as a result of root canal treatment.

Key-words: Tooth reimplantation; tooth mobility

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Periodontometry has been developed as a diagnostic method for measuring tooth mobility. It appears, however, that this factor has never been examined in a clinical or experimental study, although increased mobility is the main feature after traumatic luxation and replantation of teeth. Periodontometry has been successfully used in assessment of traumatic occlusion and evaluation of the effect of periodontal treatment and orthodontic movement of teeth (*Mühlemann*, 1960, 1967). As this method registers tooth mobility quantitatively, it was felt worthwhile to use periodontometry in the assessment of periodontal healing following replantation. The purpose of the present study was therefore to study tooth

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Table I. *Clinical data for replantation material*

Case no.	Sex	Age	Tooth location (FDI nomenclature)	Extra oral period dry (min)	Extra oral period wet (min)	Total extra oral period (min)	Splinting period (weeks)	Time before root canal treatment (weeks)	Observation period (weeks)
1	♂	15	21	20	0	20	2	2	52[1])
2	♂	10	21	5	5	10	2	2	52[1])
3	♂	24	21	20	0	20	1	3	52[1])
4	♂	21	11	1	0	1	1	12	26[1])
5	♂	9	11	3	12	15	1	4	52[1])
6	♂	24	21	35	0	35	1	9	26[1])
6	♂	24	22	35	0	35	1	9	26[1])
7	♂	32	21	140	35	175	1	8	26[2])
8	♂	9	21	105	0	105	2	2	8[2])
9	♂	13	11	140	30	170	2	1	26[2])
9	♂	13	21	140	30	170	2	1	26[2])
10	♂	39	21	80	0	80	2	2	52[2])
10	♂	39	22	80	0	80	2	2	52[2])
11	♀	10	21	80	0	80	2	2	8[2])
12	♂	18	21	25	10	35	2	2	8[2])
13	♂	9	21	21	4	25	1	4	6[2])
14	♂	13	11	70	0	70	1	4	16[2])
14	♀	13	21	70	0	70	1	4	16[2])
14	♀	13	22	70	0	70	1	4	16[2])
15	♀	14	21	20	40	60	2	2	16[2])
16	♂	24	11	55	0	55	2	2	8[2])
17	♀	7	21	105	0	105	2	2	8[2])
18	♂	30	12	30	35	65	2	2	8[2])
19	♀	10	11	30	0	30	1	6	26[2])
20	♂	6	21	60	0	60	1	- -	16[2])
21	♂	14	11	27	5	32	2	6	8[2])
22	♀	10	11	65	0	65	2	2	8[2])
23	♂	6	21	60	0	60	2	5	26[3])
24	♀	7	22	0	105	105	6	2	52[3])
25	♂	13	11	14	72	86	6	2	52[3])
26	♂	8	41	1	44	45	2	1	52[3])
27	♀	24	21	55	0	55	2	2	52[3])
28	♂	9	21	7	8	15	1	4	52[3])
29	♂	15	41	15	0	15	1	16	52[3])
30	♀	10	11	70	0	70	5	5	52[4])
31	♂	18	11	25	15	40	1	10	52[4])
32	♂	7	11	30	0	30	12	13	52[4])
33	♀	10	11	5	5	10	1	6	52[4])
34	♀	7	11	30	0	30	5	11	52[4])
35	♀	7	21	30	0	30	5	11	52[4])

[1]) Healing. [2]) Permanent replacement resorption. [3]) Transient replacement.
[4]) Inflammatory resorption.

mobility changes after replantation of avulsed permanent teeth and to correlate these data with radiographic and clinical findings.

MATERIAL AND METHODS

The clinical material consisted of 35 patients in whom a total of 40 permanent teeth were replanted. All teeth were avulsed due to traumatic injuries. The clinical data for these patients including observation periods are listed in Table I.

The following replantation procedure was used: The avulsed tooth was placed as soon as possible in saline. If the tooth was obviously contaminated it was cleased with gauze soaked in saline. The tooth was replanted in its socket by digital pressure. No efforts were taken to sterilize the root surface.

An orthodontic band-acrylic splint was applied asually for one or two weeks (*Andreasen*, 1971). In all cases penicillin (2×10^6 i.u.) was administered for 3—4 d. Root canal treatment was generally instituted 10 to 14 d after replantation. The pulp was extirpated and the pulp canal was enlarged with a file no. 5 (Giro file®, Micro Mega) operated in a special contra-angle handpiece (Giromatic®, Micro Mega). The root canal was cleansed with a 1 % sodium hypochlorite solution followed by a 3 % hydrogen peroxide solution and saline. The root canal was in 31 cases obturated with guttapercha and a root canal sealer (Kerr Pulp Canal Sealer®, Kerr Co.) using a lateral condensation technique and in 6 cases with calcium hydroxide (Calasept®, Scania Dental AB, Hägersten, Sweden). In three cases the vitality of the pulp was restored after replantation. The periodontometer used was a modified macroperiodontometer as devised by *Mühlemann* (1960, 1967). An impression tray with a dial indicator was fixed in the mouth with plaster of paris. The indicator's pointer was oriented perpendicular to the labial surface of the tooth to be measured. The indicator was placed 2 mm from the incisal edge and at equal distances from the mesial and distal side of the tooth. The labial and palatal deflection was made with a dynamometer. The tooth under examination was pushed by the dynamometer from its rest position into a labial and later lingual position by 100 gram force. The excursion was indicated in mm $\times 10^{-2}$. Three readings were made in each case and the average of the combined labial and lingual excursions were calculated as the mean mobility for the tooth examined. In each case a non-involved incisor and if possible contralateral incisor was used as a control tooth. All readings were carried out between 8 a.m. and 12 a.m.

Mobility testings were carried out at the following intervals after replantation: 1, 2, 3, 4, 6, 12, 16, 26 and 52 weeks. At the same time intraoral radiographs were taken at 65 KV using a standardized bisecting angle technique (*Updegrave*, 1967). The radiographs were processed in an automatic film processor (Siemens, Dentimatic®) with automatic replenisher. The degradation of the processing solutions were measured by densitometry readings of control films which have been produced from a specially designed 6 level step aluminium wedge. The variation of the densitometry readings were found to be $\pm$ 10 %. The radiographs were examined using an illuminator with diffuse white light. The radiographic evaluation was carried out in a darkened room and the radiographs were masked so that light could not pass beside the film. The radiographs were examined both with naked

eye and using a magnifying glass large enough to allow binocular observation. The radiographs were evaluated blindly in relation to mobility values and results of percussion test.

The precision of the mobility testing procedure was determined from 12 double determinations of mobility readings performed with 24 hours interval. The precision was calculated from the formula $s(i) = \sqrt{\frac{\Sigma(d)^2}{2n}}$ where d is the difference between duplicate registrations and n is the number of registrations.

The precision of the radiographic technique was determined from 10 radiographs taken at 6-week intervals. The length of the tooth was measured on the radiographs with a sliding caliper and this measure was used as an expression of the precision of the radiographic technique.

Ankylosis was diagnosed clinically in the follow-up period by the percussion test. This test was carried out by tapping the tooth lightly with the handle of a mouth mirror in vertical as well as horizontal direction. Ankylosis was diagnosed when the percussion sound was high differing clearly from adjacent non-injured teeth.

A randomisation test for independent samples was used in the statistical analysis and a significance level of 5 % was chosen as the critical probability value (*Siegel*, 1956).

RESULTS

The precision of the mobility testing and the radiographic technique were found to be 0.018 mm and 0.26 mm respectively.

The combined clinical, radiographic and mobility findings revealed that healing after replantation could be divided into the following four groups:

Group 1. Normal healing with slightly increased or normal mobility values, and no radiographic sign of progressive root resorption.

Group 2. Permanent replacement resorption with lowered mobility values and radiographic sign of replacement resorption. Decreased mobility values indicate that ankylosis was usually evident 5 weeks after replantation. At the same time, it was possible to diagnose the ankylosis by the percussion test. The radiographic examination first revealed ankylosis 8 weeks after replantation.

Group 3. Transient replacement resorption with lowered mobility values which later became normal. Radiographic signs of a transient replacement resorption were present in some cases.

Group 4. Inflammatory resorption with increased mobility values and radiographic sign of inflammatory root resorption. Mobility values tended to become normal when inflammation subsided as a result of root canal treatment.

In Table II the mobility values are listed for 5 teeth exhibiting normal clinical and radiographic conditions after replantation. It appears that the initially very high mobility values showed a rapid decrease in the first 3 weeks and then became relatively stabilized at a slightly increased level in relation to the control teeth. In two cases normal mobility values for the replanted tooth was registered 8 weeks after replantation. In the remaining cases the mobility values became stationary at a slightly increased level (Fig. 1).

In Table II the mobility values are listed for the group exhibiting permanent replacement resorption. It appears that the initial rapid decline in mobility are identical to the group with normal healing but, unlike this group, the mobility

Table II. *Mobility values for different healing groups*

Observation period (weeks)	Group	Normal healing				Permanent replacement resorption				Transient replacement resorption				Inflammatory resorption			
		n	$\bar{x}$ mm $\times 10^{-2}$	S.D.	Range	n	$\bar{x}$ mm $\times 10^{-2}$	S.D.	Range	n	$\bar{x}$ mm $\times 10^{-2}$	S.D.	Range	n	$\bar{x}$ mm $\times 10^{-2}$	S.D.	Range
1	Replant	3	35.1	11.96	21.5—44.0	10	40.5	11.52	18.0—56.0	2	44.2	9.97	37.2—51.3	2	52.7	21.56	37.5—68.00
	Control	1	10.7	—	—	3	9.7	3.95	6.6—15.4	1	14.3	—	—	2	15.4	6.85	10.6—20.3
2	Replant	4	32.4	11.77	20.6—33.4	22	24.9	9.86	7.8—41.8	5	25.5	15.03	14.0—51.6	1	48.0	—	—
	Control	3	12.1	3.87	8.5—16.2	14	8.8	2.58	4.6—13.5	5	16.0	6.69	8.5—24.0	1	16.3	—	—
3	Replant	4	25.1	7.21	17.3—32.6	22	15.7	7.24	1.3—34.0	4	16.7	6.68	9.3—25.3	2	31.7	3.18	29.5—34.0
	Control	3	10.2	6.42	9.5—10.7	16	9.7	4.06	5.0—19.3	4	12.1	5.47	8.6—20.3	2	12.9	6.22	8.5—17.3
4	Replant	4	23.8	8.01	13.4—31.1	21	4.3	7.82	1.5—29.0	4	11.5	44.1	6.3—17.0	1	15.4	—	—
	Control	4	13.1	5.70	8.8—21.4	18	9.7	3.73	5.0—16.0	3	11.5	3.00	9.8—16.0	1	8.6	—	—
6	Replant	2	21.8	0.00	21.8—21.8	19	3.3	4.95	0—20.2	3	4.6	3.76	2.2— 9.0	3	20.0	9.56	13.4—31.0
	Control	2	11.5	5.65	7.5—15.5	19	8.5	2.86	4.8—15.1	3	9.7	3.49	6.6—13.5	3	11.7	3.50	9.5—15.8
8	Replant	4	18.8	7.21	11.7—28.6	21	3.5	6.22	0—22.3	5	5.0	4.34	1.1—11.9	1	27.8	—	—
	Control	4	13.2	8.27	8.0—25.6	18	8.2	3.39	4.0—18.7	5	9.4	2.06	8.0—13.0	1	16.2	—	—
16	Replant	4	18.3	7.26	12.0—28.8	10	1.5	2.62	0— 8.3	6	5.0	3.91	1.0—11.0	4	22.9	9.94	16.7—37.8
	Control	4	12.4	2.92	10.5—16.7	8	8.0	1.35	6.3—10.5	6	10.1	2.55	6.5—14.3	4	10.9	3.15	8.1—14.2
26	Replant	3	14.3	7.78	9.0—23.3	6	0.7	0.81	0— 2.0	7	7.2	3.75	2.5—13.0	6	15.9	2.96	12.0—20.3
	Control	3	12.9	8.22	7.0—22.3	4	8.4	3.17	6.0—13.0	6	7.3	1.79	6.6— 9.5	4	9.7	2.98	7.3—14.1
52	Replant	4	12.6	6.13	8.1—21.0	2	0.0	0.00	0	6	9.9	3.38	4.5—13.6	6	12.6	4.09	7.0—19.6
	Control	4	11.5	6.26	6.5—14.4	2	7.7	1.06	7.0— 8.5	6	7.3	1.79	5.0—10.0	4	8.3	2.74	5.1— 8.3

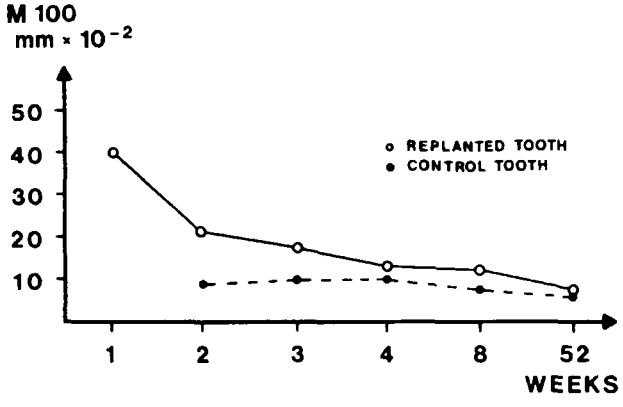

Fig. 1. Normal healing with slightly increased mobility values (Case no. 5).

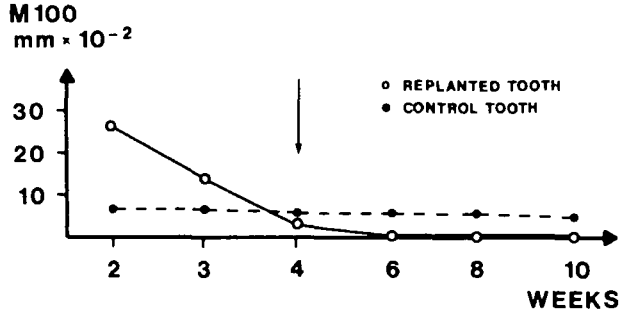

Fig. 2. Permanent replacement resorption. Mobility values indicated that an ankylosis was established 4 weeks after replantation. Replacement resorption was first radiographically demonstrable 6 weeks after replantation, arrow (Case no. 8).

decreases in the following weeks leading to a permanent ankylosis (Fig. 2).

In Table III the combined results of the clinical and radiographic examination are listed according to the length of the post-injury period after which the different examination methods revealed an ankylosis. It appears that ankylosis usually was diagnosed by the mobility testing and the percussion test 5—6 weeks after replantation. A radiographic demonstration of ankylosis was first possible only after 8 weeks (Fig. 7).

In Table IV the mobility values are

Table III. *Diagnosis of replacement resorption by different examination procedures*

	Mobility testing (weeks before diagnosis)		Percussion test (weeks before diagnosis)		Radiographic examination (weeks before diagnosis)	
	Median	Range	Median	Range	Median	Range
Permanent replacement resorption	5	3—36	6	3—36	8	5—26

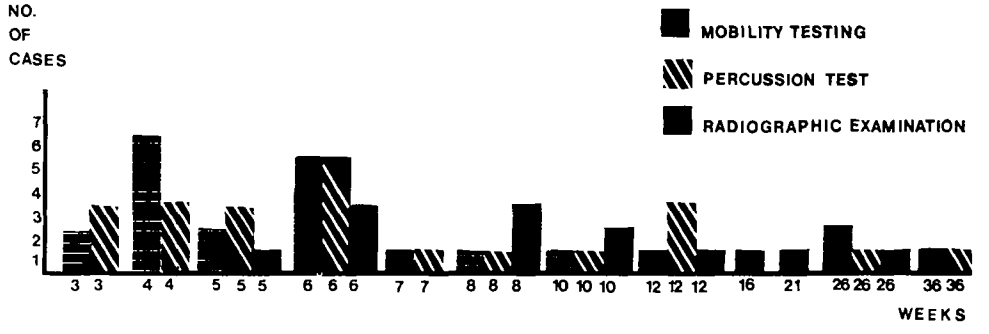

Fig. 3. Histogram demonstrating the time elapsed before diagnosis of replacement resorption by different examination procedures. In 9 cases replacement resorption was not to be demonstrated radiographically.

given for the group which demonstrated a transient ankylosis. It appears from Fig. 4 that this condition was diagnosed in the period from 6 to 52 weeks after injury. In a single case this condition was of only 6 weeks duration, whereas other cases showed a longer duration. In a few cases this change in replacement resorption was also demonstrated radiographically (Figs. 5 & 6).

In Table II, mobility values are shown for teeth exhibiting inflammatory resorption. It appears that mobility values tended to remain increased in relation to the control teeth. Four teeth in this group were endodontically treated with calcium hydroxide and two teeth with guttapercha. As periapical inflammation subsided a decrease in mobility values was found (Fig. 7).

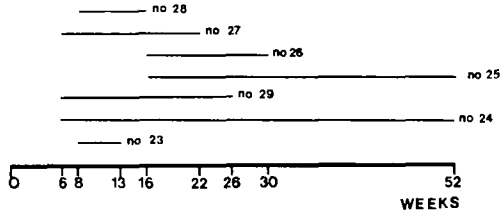

Fig. 4. Graphic illustration of transient replacement resorption diagnosed by mobility testing. The solid line indicates the period of transient replacement resorption.

In Table IV, the clinical data are compared for the different healing groups. The groups exhibiting normal healing was characterized by very short extraoral periods. A comparison between the teeth exhibiting transient replacement resorption had a significantly shorter dry extraoral period compared to teeth with permanent replacement resorption.

Table IV. *Clinical data related to healing groups*

	Normal healing			Permanent replacement resorption			Comparison between permanent and transient replacement resorption	Transient replacement resorption			Inflammatory resorption		
	$\bar{x}$	S.D.	Range	$\bar{x}$	S.D.	Range	p	$\bar{x}$	S.D.	Range	$\bar{x}$	S.D.	Range
Age	18.1	6.71	9—24	16.7	10.27	6—39	0.18	11.7	6.31	6—24	9.8	4.26	7—18
Extraoral period dry (minutes)	17.0	14.50	1—35	70.6	39.58	20—140	0.005	21.7	25.15	0—60	31.6	21.13	5—70
Extraoral period wet (minutes)	2.4	4.61	0—12	9.4	14.87	0— 40	0.21	32.7	42.26	0—105	3.3	6.05	0—15
Total extraoral period (minutes)	19.4	12.47	1—35	80.0	45.01	25—175	0.17	54.4	33.62	15—105	35.0	19.74	10—70
Splinting period (weeks)	1.2	0.48	1—2	1.6	0.48	1—2	0.26	2.8	2.19	1—6	4.8	4.02	1—12
Time before root canal treatment (weeks)	5.8	4.05	2—12	2.8	1.97	1—8	0.63	4.5	5.22	1—16	9.3	3.14	5—13

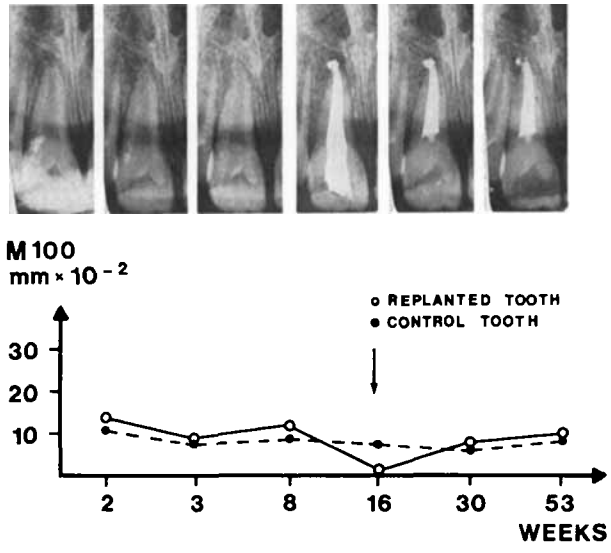

Fig. 5. Transient replacement resorption. Mobility testing indicates an ankylosis 16 weeks after replantation. Ankylosis is also demonstrable radiographically (arrow). A. Normal periodontal space is restored at later controls (Case no. 26).

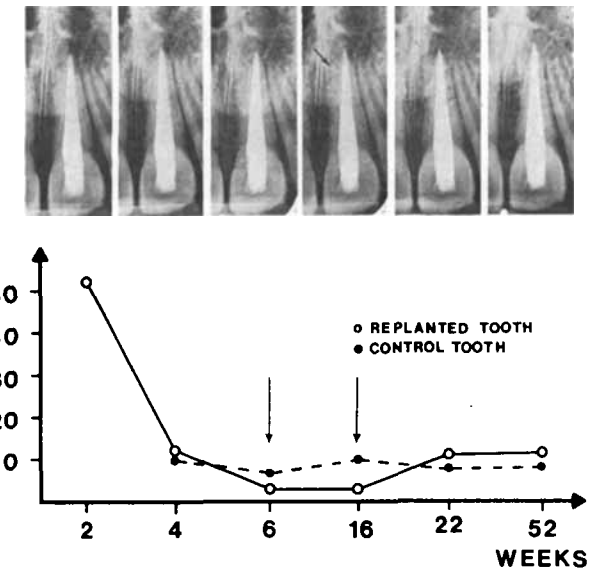

Fig. 6. Transient replacement resorption. Mobility testing indicates an ankylosis 6 and 16 weeks after replantation. A slight obliteration of the periodontal space is evident radiographically 16 weeks after replantation (arrow). A periodontal space is restored radiographically 52 weeks after replantation (Case no. 27).

DISCUSSION

The Mühlemann technique used in this study to assess mobility changes appeared to be a reliable indicator af healing processes in the periodontium. Thus the different resorption types showed characteristic changes in mobility values. A surprising finding was that mobility values of teeth splinted for only one week tended to reach normal levels 3 weeks after replantation. This indicates a rapid repair of the periodontium.

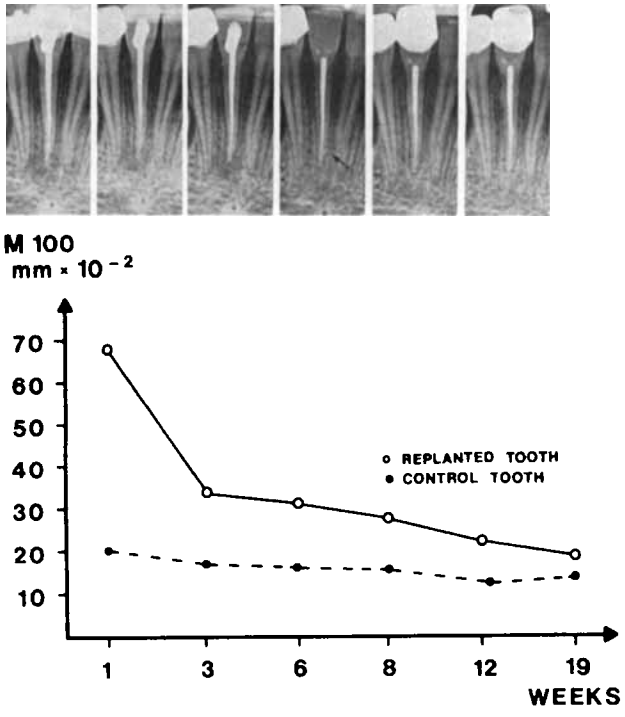

Fig. 7. Inflammatory resorption with increased mobility values. Inflammatory resorption is evident radiographically 6 weeks after replantation (arrows) and root canal treatment with calcium hydroxide was instituted. After 19 weeks root resorption is arrested and a normal periodontal space re-established (Case no. 33).

The above mentioned healing sequence is apparently in conflict with current treatment procedures of replanted teeth where splinting is maintained for 8—12 weeks (*Ellis & Davey*, 1970; *Hargreaves & Craig*, 1970). Such extended splinting periods seem not only to be superfluous, but a recent study has shown that this may actually induce replacement resorption under certain conditions in monkeys (*Andreasen*, 1975).

The reason for the mobility values of replanted teeth to became stationary at a slightly elevated level after an initial rapid decline is possibly related to the root canal treatment. In this period the teeth showed radiographic signs of periapical rarefaction due to pulp necrosis. When periapical healing took place this was also followed by a normalization of the mobility values (Fig. 7).

Permanent replacement resorption was mainly diagnosed 5—6 weeks after replantation by mobility and percussion testing. These methods were found to be far more reliable than the radiographic examination. In some cases mobility testing indicated ankylosis before this could be demonstrated by the percussion test. Mobility testing is, therefore, of special value in the early diagnosis of replacement resorption, a fact that may be of importance when early treatment procedures are attempted for the elimination of replacement resorption.

The transient ankylosis which was revealed by the changes in mobility was a surprising finding. This type of repair has not been previously described in the literature. However, histologic evidence from replantation studies in monkeys and surgical injuries to the periodontium in rats support the assumption that a transient ankylosis may occur as a part of healing processes after surgical or traumatical injuries to the periodontium

(*Andreasen*, 1975; *Andreasen & Skovgaard*, 1972).

The explanation for the transient replacement resorption could be that this resorption type represents cases with a limited injury to the periodontium, leading to a few ankylosis areas. These resorption areas may possibly be removed by a functionally stimulated resorption process. In the permanent replacement resorption group, the damage inflicted upon the root surface is supposedly so extensive that it leads to a massive ankylosis which cannot be removed by a functionally stimulated resorption process. The significant difference in the length of the extraoral dry period for the two replacement resorption types merely support this theory.

The increased mobility values recorded after inflammatory resorption appeared to reflect the destruction of the collagenous fiber arrangement in the periodontium due to the inflammatory changes. Thus, in the phase of periapical healing, a decrease in mobility values were found. Mobility testing thus appeared to be an indicator for the amount of periapical inflammation.

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REFERENCES

Andreasen, J. O. 1971. Fiksation med orthodontisk bånd-akrylskinne. En ny fiksationsmetode til traumatisk løsnede permanente tænder. Tandlaegebladet 75, 404—407

Andreasen, J. O. 1975. The effect of splinting upon periodontal healing after replantation of permanent incisors in monkeys. Acta Odont. Scand. 33, 313—323

Andreasen, J. O. & Skougaard, M. R. 1972. Reversibility of surgically induced dental ankylosis in rats. Int. J. Oral Surg. 1, 98—102

Ellis, R. G. & Davey, K. W. 1970. *The classification and treatment of injuries to the teeth of children.* Year Book Medical Publishers, Chicago. 5. ed.

Hargreaves, J. A. & Craig, J. W. 1970. *The management of traumatised anterior teeth of children.* E. & S. Livingstone, London

Mühlemann, H. R. 1960. 10 years of tooth-mobility measurements. J. Periodont. 31, 110—122

Mühlemann, H. R. 1967. Tooth mobility: A review of clinical aspects and research findings. J. Periodontol. 38, 686—708

Siegel, S. 1956. *Nonparametric statistics for the behavioral sciences.* McGraw-Hill Book Company, New York, pp. 152—156

Updegrave, W. J. 1967. Simplified and standardized bisecting-angle technique for dental radiography. J. Am. dent. Assoc. 75, 1361—1368