UiT The Arctic University of Norway

Institute of Clinical Odontology

Technical quality of root-filled teeth performed by undergraduate students at UiTs student clinic

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Abstract

This retrospective study aims to evaluate the technical quality of root fillings performed at the UiT student clinic between 2011 and 2021, and reveal factors influencing the quality.

The sample consisted of 474 periapical radiographs of endodontically treated teeth. All cases were treated by 4th and 5th year undergraduate students at UTK, from 2011 to 2021. Each root was independently evaluated in multirooted teeth, but the tooth was considered one unit when categorized. The evaluation was based on length and density of the root canal filling. The presence of iatrogenic errors was also recorded. Cohen's kappa was used to measure the inter-examiner agreement. Frequency comparisons were calculated using Chi-square test.

The results show that 72,4% of the evaluated teeth had a complete root filling. Number of canals and treatment sessions, presence of curved canals and the tooth position in the dental arch (posterior vs. anterior) significantly affected the technical quality. Iatrogenic mistakes were found in 20,9% of the sample, with ledge accounting for more than half (56,6%).

Overall, the technical quality of root fillings performed by undergraduate students at UiT was satisfactory.

Keywords: root canal filling, technical quality, undergraduate, iatrogenic mistake

1. Introduction

Endodontics is concerned with *"all structures and processes within the tooth, with particular reference to the dental pulp and the space it occupies"* (1). The treatment goal is to prevent or cure apical periodontitis and thereby ensure healthy periradicular tissue (2).

Root canal treatment consists of removing inflamed, infected, or necrotic pulp and disinfecting, shaping, and sealing of the root canal. Radiographically the root filling should not be more than 2mm from the radiographic apex and there should be no void laterally or apically between the filling and the canal wall (2). A root canal filling of good technical quality is essential for the survival of the tooth and surrounding bone structure (3). Several previous studies have shown a significant correlation between good technical quality of root fillings and favorable outcome (3-6) or indicated a trend (4).

Dentists' knowledge and technical abilities are crucial for optimal root canal treatments. According to guidelines issued by the European Society of Endodontology (ESE) *"Every dental practitioner is expected to be able to recognize and treat effectively pulpal and periapical injuries and diseases that are commonplace and within the skills acquired by graduates of dental schools in Europe"* (2). In addition, practitioners should evaluate the tooth's level of difficulty and refer to a more experienced dentist or specialist if the level exceeds their limitations (7, 8).

Between endodontists, general dental practitioners, and undergraduate students, technical quality of root canal fillings varies. According to a recent study from Turkey, the technical quality of 4th-year undergraduates, 5th-year undergraduates and endodontic specialists were 52, 63,1 and 86,5% respectively (9). Undergraduate studies in Europe show a wide range of acceptable qualities, varying from 13 to 84,1% (6, 10-17).

The difference in quality may be dependent on numerous factors. Several studies reported lower rates of acceptable root canal treatment in molar roots compared to incisors (6, 13-15). The results may relate to molars having a more complicated root canal anatomy regarding canal curvature and number of canals. Molars also have a more posterior placement in the dental arch, decreasing visibility and access to the root canals. Since the technical quality of different tooth types varies, the distribution of treated teeth included in the studies will affect the overall technical quality.

Another factor contributing to the difference in root filling quality is root canal preparation technique. An undergraduate study reported significantly better root filling homogeneity when using rotary files compared to stainless steel hand files (11). Abu-Tahun et al. (18) states that the use of rotary instruments leads to an enhanced technical quality, especially for clinicians with less experience, such as undergraduate students. Another technical procedure that might differ is obturation technique. Cold lateral condensation is primarily taught in undergraduate courses (19) and frequently reported as applied technique in undergraduate studies (6, 9, 10, 13, 14, 16, 17). However, a recent study where undergraduate students used reciprocating root canal instruments and corresponding single cone obturation technique, reported that 62,5% of root-filled teeth had adequate technical quality (20). In addition, the quality of preclinical education and the supervisors' qualifications in clinical training can affect the quality of root fillings completed by undergraduate students (16).

There are two types of endodontic treatments, and they are differentiated by the pulp status. Primary treatment is performed on teeth that has not been endodontically treated earlier, while secondary treatment (retreatment/revision) is performed on previously root-filled teeth, because primary treatment failed (4, 6, 21)**.** Secondary treatment is considered a more technically sensitive procedure and is affected by previous procedural errors. Therefore, retreatment may lead to a lower percentage of good technical quality root fillings.

The technical quality of root canal fillings performed by students attending The Arctic University of Norway (UiT) have previously been evaluated and presented in two master projects. The first master thesis assessed endodontic treatment between 2007 and 2010 (22), and reported good technical quality (57%). The second master thesis (2013) also evaluated outcome and the results showed a high success rate (81-92%), but only 40% of the root fillings were categorized as complete (23).

This study aims to evaluate the technical quality of root canal fillings performed at the UiT student clinic between 2011 and 2021, and reveal factors influencing the quality.

2. Material and Methods

The sample consisted of 474 periapical radiographs of endodontically treated teeth. Each case had a corresponding form with relevant diagnostic and treatment information (appendix 1). All cases were treated by 4th and 5th year undergraduate students at UTK (Universitetstannklinikken), from 2011 to 2021. The study only included endodontic treatment carried out entirely by undergraduate students, excluding cases that were referred to a more experienced practitioner beforehand and during treatment. Radiographs not showing the entire root were excluded from evaluation. The number of excluded teeth was not registered.

Two students (LN and LJ) were first calibrated, using 20 radiographs, until sufficient constancy was reached. The calibration was only based on discussion with an endodontist (RK). A new set of 20 radiographs was then used to evaluate the agreement between the two students. These radiographs were not a part of the sample. Cohen's kappa coefficient was used to measure the consensus between the observers. It was calculated to be 0,82, which is acknowledged to be a strong degree of agreement (24).

Post-treatment periapical radiographs were used to assess the technical quality of the root canal fillings. Each root was independently evaluated in multirooted teeth, but the tooth was considered as one unit when categorized. The least favorable root was selected when categorization differed between the roots in a tooth. The evaluation criteria were technical quality of the root filling, based on length and density, and the presence of iatrogenic errors. Root fillings were categorized as:

Complete: Root filling 0-2 mm from the radiographic apex with no visible voids within the root filling or between the root filling and root canal wall.

Incomplete apical: Root filling ending more than 2mm from the radiographic apex, or

visible void between the apex and root filling.

Incomplete lateral: Void between the root filling and lateral canal wall.

Incomplete apical and lateral: A combination of root filling ending more than 2mm from the radiographic apex or visible void between the apex and root filling, and void between the root filling and lateral canal wall.

Partially filled tooth: A lack of root canal filling material in one or more canals in a multirooted tooth.

Complete fillings refer to root fillings of good technical quality, while the other categories refer to not acceptable technical quality.

Iatrogenic mistakes, which is procedural accidents, can interrupt and even compromise canal cleaning, shaping and obturation, resulting in an incomplete filling (15). We defined iatrogenic mistakes according to Van der Vyver et.al. (25) as:

Ledge: Artificially created irregularity in the canal wall.

Apical transportation: Alteration of the form and placement of the apical foramen, resulting in its enlargement.

Apical perforation: Communication between the root canal and surrounding periodontal tissue in the apical region.

Furcation perforation: Communication between the root canal and surrounding periodontal tissue in the furcal region.

Separated instruments: Fracture of an instrument within the canal.

Root canal treatment was performed according to standard protocol at UTK: Cavity preparation followed the outline form, shaped according to pulpal anatomy. Straight-line access to the root was ensured. Working length was determined using an apex locator and confirmed with apical radiography. Root canals were shaped with Ni-Ti files, either hand- or

rotary instruments. Hand files were used in a balance force technique. ProTaper Universal were used in earlier years, while ProTaper Next is the currently available rotary instrument at the student clinic (Dentsply Sirona. Charlotte USA). Root canals were filled using cold lateral condensation.

Results are presented in numbers and percentages. Frequency comparisons were calculated using the Chi-square test, and the p-value for statistical significance was set to 0,05. The data analysis was performed using the statistical program package IBM SPSS Statistics 26.0. (IBM. New York, USA).

3. Results

Table 1. Technical quality of root canal fillings

Technical quality		**Teeth N (%)**
Complete		343 (72,4)
Incomplete		131 (27,6)
	Incomplete apical	94 (19,8)
	Incomplete lateral	23 (4,9)
	Incomplete apical and lateral	12 (2,5)
	Partially filled tooth	2 (0,4)
Total teeth		474

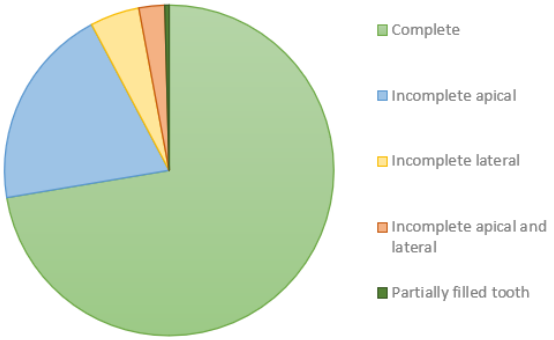

Figure 1. Technical quality of root canal fillings

The results from the technical quality evaluation of the root fillings are summarized in Table 1 and visualized in Figure 1.

Out of all evaluated teeth 343 (72,4%) had a complete root filling, both apically and laterally. More than 2mm distance or void between root canal filling and radiographic apex was the most frequent reason for incomplete root filling (19,8%).

Table 2. Frequencies of potential influencing factors and their association to the technical quality of root fillings

Relating factors \ Technical quality		Complete N (%)	Incomplete N (%)	Total N
Student year	**4th year**	101 (78,9)	27 (21,1)	128
	5th year	242 (69,9)	104 (30,1)	346
Preparation technique	**Rotary**	120 (71,9)	47 (28,1)	167
	Hand instrumentation	223 (72,6)	84 (27,4)	307
Curvature	**No curvature**	209 (78,3) *	58 (21,7)	267
	1 or more canals with >30° curvature	134 (64,7) *	73 (35,3)	207
Number of canals	**1-2 canals**	212 (80,3) *	52 (19,7)	264
	≥3 canals	131 (62,3) *	79 (37,6)	210
Location (dental arch)	**Anterior**	73 (85,9) *	12 (14,1)	85
	Posterior	270 (69,4) *	119 (30,6)	389
Location (jaw)	**Maxilla**	206 (73,0)	76 (27,0)	282
	Mandibula	137 (71,4)	55 (28,6)	192
Number of treatment sessions	**1-4 sessions**	310 (74,9) *	104 (25,1)	414
	5-10 sessions	34 (56,7) *	26 (43,3)	60
Type of treatment	**Primary**	300 (71,3)	121 (28,7)	421
	Secondary/retreatment	43 (81,1)	10 (18,9)	53
Extruded material	**None**	274 (70,8)	113 (29,2)	387
	Present	69 (79,3)	18 (20,7)	87

*p-value ≤ 0,05

Frequencies of potential influencing factors and their association to technical quality of root fillings are presented in Table 2.

The amount of canals and treatment sessions, the presence of curved canals and the tooth's position in the dental arch significantly affected the technical quality of root fillings.

209 teeth with straight canals had significantly better technical quality (78,3%) than 134 teeth with canal curvature (64,7%). Teeth with one or two canals had significantly higher percentage of complete root fillings compared to teeth with three or more canals, 80,3% and 62,3% respectively. Teeth with anterior position in the dental arch showed 16,5% higher tendency of complete root fillings than posterior teeth. When treatment was completed in one to four sessions technical quality was significantly better than treatment completed in five or more sessions (74,9% vs. 56,7%).

A significant difference in the technical quality was not found between 4th and 5th year students or when comparing primary and revision, maxilla and mandibula and preparation technique. However, 4th year students had higher percentage of good technical quality than 5th year students, 78,9% and 69,9% respectively. Primary root-filled teeth had acceptable quality in 71,3% of the cases, compared to 81,1% in retreated teeth. Root canal fillings with root filling material extruded into the periapical bone tissue were more often categorized having good technical quality compared to teeth with root fillings terminated before the radiographic apex.

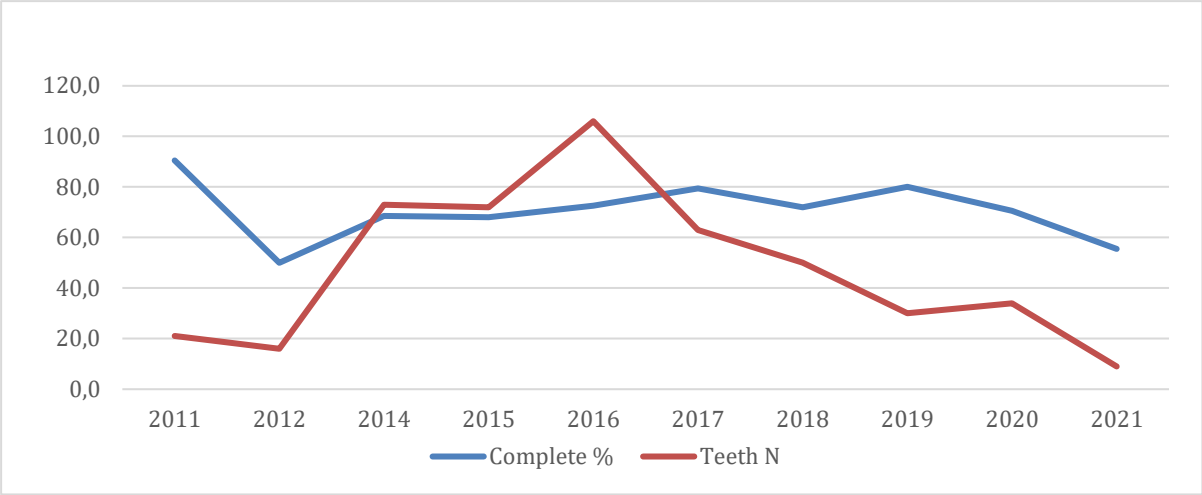

Figure 2. The difference in technical quality and number of treated teeth from 2011 to 2021.

The total number of teeth treated per year (colored red) and the corresponding technical quality (colored blue) is presented in Figure 2. The proportion of complete root fillings varied from 50,0 to 90,5% throughout the years, the percentage was 55,6 in 2021. The technical quality was relatively stable from 2014 to 2020, while the number of treated teeth varied considerably. The number has been declining the last 5 years, from 106 in 2016 to 9 in 2021. Unfortunately, there was no data available from 2013.

Table 3. Prevalence of iatrogenic mishaps and corresponding technical quality

Iatrogenic mishaps	**Complete N (%)**	**Incomplete N (%)**	**Total N (%)**
Ledge	20 (35,7)	36 (64,3)	56 (56,6)
Apical transportation	2 (33,3)	4 (66,7)	6 (6,1)
Apical perforation	18 (90)	2 (10)	20 (20,2)
Furcation perforation	1 (100)	0 (0)	1 (1,0)
Separated instrument	3 (75)	1 (25)	4 (4,0)
Other	7 (58,3)	5 (41,7)	12 (12,1)
Total n teeth with iatrogenic mistake	51 (51,5)	48 (48,5)	99 (20,9)

Table 3 shows the distribution of procedural errors that occurred during root canal treatment. A total of 99 treated teeth (20,9%) had an error, with ledge accounting for more than half (56,6%). Teeth with ledges and apical transportation had the highest percentage of incomplete technical quality. It is to be noted that even if the tooth had an error, the tooth could still be categorized as complete.

4. Discussion

The results show that 72,4% of 474 sampled teeth had an adequate root canal filling. Compared to other undergraduate studies (6, 10-17) ours is at the higher end of the range regarding technical quality of root canal fillings. All studies used the same obturation technique but variated in aspects such as included tooth type (single-rooted or both single- and multi-rooted), type of treatment (primary or both primary and secondary) and preparation technique (hand vs. rotary instruments). For example, Lynch et. al. only evaluated single rooted teeth, others evaluated all types (6, 13-15).

The most frequent reason for inadequate technical quality was more than 2 mm distance (short root filling) or void between root filling and radiographic apex (19,8%). This is problematic when treating necrotic teeth because the apical part of the root canal retains biofilm, that might compromise the treatment outcome (26). Fong et. al. (12), Lynch et. al. (10) and Unal et. al (13) also reported underfilling as the most recorded reason for inadequate root canal filling.

The number of canals per tooth was significantly correlated to the tooth's technical quality. Teeth with 3 or more canals had acceptable quality in 62,3% of the cases, while teeth with 1 or 2 canals were complete in 80,3%. A tooth with a high amount of canals is more likely to be categorized as inadequate because of categorization method (root vs. tooth). In this study, the tooth was evaluated as a unit and the technical quality was more often categorized as adequate (72,4%) compared to the two previous studies conducted at UiT. The first study (22) evaluated each canal separately and had a higher technical quality (57%) than the second study (23) which evaluated the tooth as a unit (40%). The correlation is also presented in a study by Unal et. al. (13): 79% of the canals had good endodontic work, while only around 74% of the teeth had good endodontic work. Also, Kumar et. al. (17) presented 38% of

multirooted canals as satisfactory and 17,5% of multirooted teeth as satisfactory. None of the other undergraduate studies compared number of canals and technical quality. A comparison can still be made since teeth with 3 or more canals are most commonly molars (27), and several studies conclude that molars have lower technical quality (6, 13-15).

The technical quality was significantly better in straight roots. Curved canals are more prone to fractured instruments, ledges, apical transportation, and apical perforations (15, 25). These iatrogenic mistakes can compromise the root canal filling process. Unal et. al. (13) states that molar teeth had lower technical quality when the canals were curved, which corresponds to this study's findings.

The tooth's location in the dental arches was significant to the technical quality. 85,9% of anterior and 69,4% of posterior root-filled teeth were adequate. It might be related to the number of canals, since anterior teeth (incisors and canines) mostly have 1 canal while posterior teeth (premolars and molars) often have 2-4 canals. It is also easier to gain access to anterior teeth. Comparisons of maxilla and mandibula showed no statistical significance, 73,0% and 71,4% respectively. Unal et. al. (13) also concludes with significant difference regarding anterior vs posterior, but not regarding maxilla vs mandibula.

The results show that numerous treatment sessions lead to significantly less adequate technical quality. Acceptable technical quality was found in 74,9% of the cases treated in one to four sessions and 56,7% of the cases treated in five or more sessions. Incorrect pretreatment difficulty evaluation, leading to a student taking on a too complex case (overestimation of abilities), might be the cause. For example, the formation of a ledge due to an inexperienced student, lack of help from supervisor and curved canal can lead to difficulties negotiating the root canals and make treatments more time consuming than expected. It is also logical to think that the risk of making iatrogenic mistakes increases when

the tooth is opened more times than necessary. Number of treatment sessions is a variable that cannot be established before treatment, but should be continuously assessed during treatment.

The root canal fillings performed by 4th year students had adequate technical quality more often than those performed by 5th year students. However, the difference is insignificant and inconsistent with results from earlier studies (9, 13) reporting that more clinical experience gives better results. The unexpected result might be due to 5th year students taking on more complex cases. The UTK guidelines state that *"4th year students should only perform primary and uncomplicated endodontic treatment"*, while 5th year students should mostly perform primary treatment, but is also allowed to execute uncomplicated secondary treatment on incisors, canines, and premolars. Maximum difficulty level of primary treatment was not defined. The decision to treat or refer is left up to the student and the supervisor, using American Association of Endodontics' (AAE) case difficulty and assessment form (7). Another possible reason why the results were not as expected is that the preclinical endodontic training is completed in the 3rd and 4th year. Therefore, the students' knowledge and technical abilities might be fresher in mind during the 4th year, especially since there were instances of students having their first endodontic case during the 5th year.

Retreated teeth had adequate technical quality more often than primary endodontically treated teeth (81,1% vs. 71,3%). This was not expected because revision is considered to have higher difficulty (7). Unal et. al (13) and Bozkurt et. al. (9) included both types of treatment and the technical quality combined was 79,5 and 57,9% respectively. These results are fairly similar to this study (72,4%), but they did not compare the technical quality between the two treatment types. Comparisons are therefore not possible. Other undergraduate studies included only primary endodontically treated teeth and the technical quality was between 55,3 and 66 percent (12, 15).

Hand instrumented teeth had a slightly higher, but insignificant (0,7%), percentage of complete root-filled teeth compared to teeth prepared using rotary instruments. However, earlier studies (11, 18) indicate an opposite trend. The discrepancy might be because of rotary instruments were used less often than hand instruments, rotary accounted for only 35,2% of all cases.

20,9% of the endodontically treated teeth had an iatrogenic mistake. Our study did not automatically categorize root-filled teeth with iatrogenic mistakes as incomplete because the length and void criteria could still be met, even if errors where present. Ledge formation was the most dominant error (56,6%) in this study; 64,3% of 56 cases was incomplete. A survey by Eleftheriadis et. al. (15) also reported a high proportion of errors as ledges, while Bozkurt et. al. (9) mainly reported fractured instruments (76,1%). Only 4% of iatrogenic mistakes in this study were fractured instruments. Haug et al. (8) reported that endodontic mishaps were significantly higher when the endodontic treatment difficulty was high. Undergraduate students are inexperienced, it requires practice to get to know tooth anatomy and endodontic techniques to prevent mistakes, especially in high difficulty cases.

This study only assessed the technical quality based on length and density of the root filling, while other undergraduate studies used additional evaluation criteria. Many included extruded material (6, 9-17), others canal form (9, 12, 17). A continuous tapered form that follows the canals original shape is ideal (2), but isn't the case when procedural errors such as ledges are present. Therefore, these studies might categorize more cases with iatrogenic mistake as incomplete compared to our study. The effect of extruded material is not agreed upon in the literature (28). This study only categorized 20,7% of teeth with extruded material as incomplete, while several other studies categorized all extruded teeth as incomplete (6, 9-17).

The quality of root canal fillings varied from 2011 to 2021. It might be due to differences in factors such as the included proportion of molars, treatment completed by 4th years students and hand instrumented teeth. The sample size was low the last 3 years, making the corresponding technical quality results less reliable. Additionally, the decline in quality the last two years might be due to changes in the teaching method because of the Covid-19 pandemic.

The relatively low number of submitted endodontic cases in recent years might be due to a lack of patients in need of root canal treatment and better case difficulty evaluation. There is also a possibility that not all the diagnostic charts were delivered to evaluation, and we consider this a bias. The number of cases from 2020 and 2021 are possibly affected by the Covid-19 pandemic, since the student clinic had no or reduced capacity. In addition, only the first four months of 2021 were available when data collection was completed. A record of excluded cases was not kept, which affects the number of treated teeth.

Grouping some of our data made it more difficult to make comparisons with other studies that either had no or different ways to divide the various categories into groups. For example, we divided location in dental arch into posterior (incisors and canines) and anterior (premolars and molars), while some other studies chose to divide them into anterior teeth, premolars, and molars (6, 12, 13).

The evaluation was carried out using conventional two-dimensional radiography, which is well known to have limitations when it comes to overlapping anatomical structures and geometrical distortions (29). The latter can affect root filling length determination since they may not be reproduced accurately (15).

5 Conclusion

Root fillings performed at the UiT student clinic between 2011 and 2021 had satisfactory technical quality (72,4%). The study revealed four significant factors influencing the quality: curvature, location in dental arch (anterior vs. posterior), number of canals and treatment sessions. These results show improvement compared to the two earlier studies conducted in 2010 and 2013. We suggest continuing the evaluation of technical quality, as well as treatment outcome based on both existing and new material.

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7 Appendix

1.

Uit/IKO/Endodonti/EK/ rev. 27-4-2015 EK-GA/ Standard of Care Retningslinjer/VEDLEGG 1

OPUS journal #: **Endodontisk diagnose og terapi skjema**
Dato:
Pasientens navn:……Alder:…….Kjønn:……
Studentens navn :……Veileder:…… Tann #.….

1. Subjektive funn:
Hovedplage…….
……..
Signifikant medisinsk historie……..
……..

Tannens historie : (Marker alle passende)

1. Traume
2. Karies
3. Kariøs eksponering
7. Rotbehandlet
4. Restaurering( )
5. Pulpakapping
6. Pulpotomi
8……

Smertens karakteristika (Marker alle passende)
0. Ingen 1. Spontan
2. Provosert (av…….)
3. Kort 3. Forlenget
4. Lokalisert 5. Diffus

Reaksjon på termal stimulus:
0. Ingen 1. Kort 2.Vedvarende

Reaksjon på mastikasjon
0. Ingen 1. Mild-Mod 2. Alvorlig

2. Objektive tegn og tester
Tann # ------ ------ ------ ------

Pulpatesting (+, -, NA(=ikke relevant?)
EPT : ------ ------ ------ ------
KULDE: ------ ------ ------ ------
Kort ------ ------ ------ ------
Vedvarende ------ ------ ------ ------

Periapikale tester:
Uten anmerkning (0) ,mild-moderat (+) ,alvorlig(++)
Perkusjon ------ ------ ------ ------
Palpasjon ------ ------ ------ ------

Periomåling ----- ------ ------ ------
Ingen lommer dypere enn 4mm □

Hevelse: 0. Fraværende 1. Tilstede
Intraoral: Lokalisert Diffus
Ekstraoral: Lokalisert Diffus
Sinusgang: 0. Fraværende 1. Tilstede

3. Radiografiske funn
0. Normal
1. Apikal radiolucens
2. Apikal rotresorpsjon
3. Apikal radiopasitet
4. Furkal radiolucens

4. Diagnose

Pulpal
1. Normal
2. Reversibel pulpitt
3. Irreversibel pulpitt
4. Nekrotisk pulpa

Periapikal
1. Normal
2. Akutt apikal periodontitt (AAP)
3. Kronisk apikal periodontitt(CAP)
- Condensing/kondenserende osteitt
4.Akutt apikal abscess (AAA)
5.Suppurativ apikal periodontitt (SAP)
WHO-ICD-10 kode: K04._____

5. Prognose før behandling

0. Gunstig
1. Usikker
2. Ugunstig

6. Behandlingsplan

Endodontisk:
Haster/akuttbehandling ……..
Definitiv behandling……
Periodontisk…….
Restaurativ…….
=> DATO OG SIGNATUR AV VEILEDER ____

7. Obturasjonsevaluering
0. 0-2 mm fra radiografisk apex (akseptabelt)
1. Overekstendert ……mm
2. Underfylt……...mm; kommentar _____
3. Tom kanal synlig apikalt for GP
4. Hulrom/buckling

8. Prognose etter obturasjon
0. Gunstig
1. Usikker
2. Ugunstig
=> DATO OG SIGNATUR AV VEILEDER ____