Postendodontic pain of minimally-invasive root canal treatment with calcium-silicate based sealer: A Randomized Clinical Trial

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Postendodontic pain of minimally-invasive root canal treatment with calcium-silicate based sealer: A Randomized Clinical Trial

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The aim of this randomized prospective clinical trial was to compare the occurrence and intensity of postoperative pain after different root canal shaping and cleaning protocols: conventional preparation (CP) using ProTaper Gold systems, and minimally invasive preparation (MP) using TruNatomy rotary system, ultrasonic-assisted irrigation (UI) and calcium hydroxide (CH).

In total, 172 patients and 184 teeth were enrolled. Root canal treatment was carried out within at least two visits. Canal obturation was performed with continuous wave technique and resin based sealer for the CP group and with sealer based obturation and calcium silicate based sealer; Endoseal TCS for the MP group. At the first day of treatment, each patient received a pain diary to write down their pain score with numeric rating scale (NRS) and date and time of analgesic intake. For the assessment of pain after canal obturation, each patient received a phone call and was asked to tell their pain score a day after treatment.

The maximum pain score after canal instrumentation, pain score after canal obturation, incidence of moderate or stronger pain and analgesic intake of 161 patients and 170 teeth were analyzed. Eighty-five teeth were included in each group. None of the pain scores or the analgesic intake showed significant difference between the two treatment groups ($P>0.05$). Even though there was no significant difference between the treatment groups, the maximum pain score and the incidence of presenting moderate or stronger pain had a tendency to be greater on tooth with greater preoperative pain score.

Minimally invasive endodontics performed with TruNatomy, UI, CH and calcium silicate based sealer seem to provoke similar postendodontic pain compared to conventional endodontics.

Keywords : minimally invasive endodontics, postendondontic pain; Trunatomy, calcium silicate-based sealer; Endoseal TCS.

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I. Introduction

Patients presenting with endodontic pain are a regular occurrence in dental practice, and root canal treatment unequivocally reduced pain prevalence (Pak et al. 2011). However, post-preparation pain in nonsurgical endodontic treatment is a common complication with a maximum incidence within the first 24 h (Pak et al.

2011, Glennon et al. 2004), and the factors responsible for the pain include mechanical preparation and obturation beyond the apex, bacteria not eliminated during primary disinfection, and the extrusion of irrigants beyond the apex (Siqueira et al. 2004). Specifically, techniques of the root canal treatment may impact the severity of posttreatment pain (Sun et al. 2018, Mostafa et al. 2020, Chalub et al. 2022, Ahmad et al. 2022).

Recently, minimally invasive endodontics, a concept that aims to preserve the structural dentin and tooth integrity, has been suggested (Burklein et al. 2015, Bóved a et al. 2015, Silva et al. 2022). The minimally invasive concept applied to root canal preparation aims to preserve more dentin at the pericervical region and includes the use of low tapered instruments for shaping (Sabeti et al. 2018). TruNatomy rotary system (Dentsply Sirona, Ballaigues, Switzerland) have been developed to fulfill this goal, and a set of the instruments was made of a maximum fluted diameter of 0.8-mm NiTi wire (Silva et al. 2022). However, conservative canal preparation may compromise the cleanness of root canal systems (Plotino et al. 2019, Lima et al. 2020). Although Silva et al. (2022) suggested that TruNatomy and ProTaper Gold systems (Dentsply Sirona) were similar in terms of untouched canal walls and remaining dentin thickness, they also found a slight difference in the percentage of dentin removal at the coronal third. Therefore, the main concern of minimal canal enlargement is its potential impact on untouched bacterial biofilm. To reduce the risk of the remaining biofilm, ultrasonic-assisted irrigation (UI) and the use of intracanal

medication such as calcium hydroxide (CH) are recommended (Caputa et al. 2019, Sadaf et al. 2021). Recent studies have shown that both UI and CH were helpful in reducing the postoperative pain (Chalub et al. 2022, Ahmad et al. 2022). There are few studies or consensus yet about the post endodontic pain of minimally invasive endodontics.

The aim of this randomized prospective clinical trial was to compare the occurrence and intensity of postoperative pain after different root canal shaping and cleaning protocols: conventional preparation using ProTaper Gold systems, and minimally invasive preparation using TruNatomy rotary system, UI and CH.

II. Materials and methods

2.1. Study design and population

This single-blinded, randomized, controlled clinical trial was designed to compare the postendodontic pain of minimally-invasive root canal treatment (RCT) and that of conventional RCT. Analgesic intake ratio and amount were also investigated. We also evaluated the influence of factors such as patient age, sex, tooth type, pulp state, apical lesion and the intensity of preoperative pain on post-endodontic pain.

The study was approved by the Yonsei Dental College, Yonsei University Institutional Review Board (number 2-2020-0003) and registered at the CRIS (clinical research information service; No. KCT0005351). All patients got explanation with written informed consent papers and signed to participate in the study. Each patient was randomly allocated to either group CP or MP. Inclusion and exclusion criteria included the followings:

Inclusion

1. Mature permanent tooth, Patient age ≥18

2. Tooth that needs root canal treatment, either with vital or necrotic pulp

Exclusion

1. Previously initiated or treated tooth
2. Endo-perio combined lesion
3. Patient who took analgesics within 24hours
4. Patients who are disable for proper communication
5. Tooth with canals that are unable to negotiate

2.2. Sample-size determination and randomization

The required sample size was calculated using G power 3.1 software (Franz Faul, University of Kiel, Germany) to facilitate comparison of two experimental groups with a significance level of 5%, a statistical power of 80% and an effect size of 0.5. Fifty three teeth per group was determined. Considering the dropout rate of 20%, our goal was to recruit at least sixty seven patients per group.

An assistant blinded to the study objectives created a computer-generated list of random numbers using the Sealed Envelope website (https://www.sealedenvelope.com/), 1:1 allocation, and using random block sizes of 6. To ensure concealment, this list was placed in a file cabinet, kept confidential, and opened by the blinded assistant only after the inclusion of the participants in the study and before the intervention. According to the random numbers on the list, each participant was provided with an enrollment number and randomly assigned to one of the two groups based on the preparation protocol: Group CP; conventional preparation (CP) using ProTaper Gold systems, and Group MP;

minimally invasive preparation (MP) using TruNatomy rotary system.

2.3. Treatment procedures

Treatments were performed at a single-center by 10 operators: 3 professors and 7 well-trained residents in the department of conservative dentistry. All treatments were finished in two or more visits. Concentration of NaOCl used in the treatment was 2.5% and that of EDTA was 18%. .

For group CP, on the first visit, access cavity was formed with high speed burs under local anesthesia: infiltration and/or block anesthesia. Canal length was measured with the aid of electronic apex locators (DentaPort Root zx II, Morita, Irvine, USA) and then periapical view x-ray was taken with initial apical file (IAF) insertion. Pulp extirpation and canal shaping was simultaneously performed with rotary Ni-Ti file system (ProTaper Gold, Dentsply). Within canal shaping process, canal irrigation with was done with NaOCl using 30gauge notched-tip needle (Sungshim Medical Co., Bucheon-si, Korea). After canal shaping, canals were soaked with NaOCl for 5minutes. If needed, freshly mixed CH paste was applied with lentulo spiral for intracanal medication.

On the second visit, in case of intracanal medication on first visit, CH paste was removed with manual irrigation. Periapical view x-ray was taken with master cone fit state. Canals were irrigated with 1mL of EDTA for 1minute followed by 1mL of NaOCl.

Then, canals were soaked with NaOCl for 15 seconds and then irrigant was replaced, 3 times repeatedly. Canals were dried with paper points and canals were obturated with ProTaper gutta percha cone and epoxy resin based sealer (AH plus, Dentsply). A heated plugger (SuperEndo Alpha 2, B & L Biotech, Ansan, Korea) was inserted into the canal to cut the master cone at the level of 5mm from the apex and backfill with warm gutta-percha injection was performed using SuperEndo Beta 2 (B & L Biotech).

For group MP, on the first visit, access opening, canal length measurement and x-ray taking was done with same protocol as group CP. Pulp extirpation and canal shaping was simultaneously performed with minimally invasive rotary Ni-Ti file system (TruNatomy, Dentsply). Canals were irrigated with NaOCl using 30G irrigation needle and passive ultrasonic irrigation (PUI) was additionally performed using portable ultrasonic device (Endosonic Blue, Maruchi, Wonju, Korea). At the end of the treatment, all canals were dried and premixed syringe type CH (Cleanical, Maruchi) was placed for intracanal medication.

On the second visit, CH was removed with manual irrigation and x-ray was taken with master cone fit state. Canals were irrigated with 1mL of EDTA for 1minute followed by 1mL of NaOCl. PUI was performed while soaked in NaOCl for 15 seconds and then irrigant was replaced, 3 times repeatedly. After canal drying, Endoseal TCS was

dispensed into the middle third of the canal using a 24-gauge needle tip. A matching-taper single gutta-percha cone (DiaDent, Cheongjusi, Korea) was inserted into the canal, and was cut with a heated plugger at the orifice level. Obtura S-Kondenser (Obtura Spartan, Earth City, MO) was used to vertically compact the gutta percha.

At the end of the first visit for both groups, ibuprofen 200mg tablets (p.r.n, maximum 6T/day) were prescribed and patients were told to intake them in case of considerable pain. For cases that root canal treatment could not be finished on the second visit, the same protocols as the second visit for canal obturation were used at the last visit.

2.4. Outcome variables

2.4.1. Preoperative clinical and radiographic evaluation

Prior to starting the treatment, each tooth was examined clinically and radiographically. Past medical and dental history taking, pulp vitality test with cold stimulation and electric pulpal test (EPT), percussion test, periodontal probing was done and presence of sinus tract and apical radiolucent lesion was recorded.

2.4.2. Preoperative and Postoperative pain

Before the administration of local anesthesia at the first visit, patients were asked to record the preoperative pain assessed using the 0-10 NRS. Along with the numeric ratings, the Wong-Baker FACES scale was also presented to the patients to help them in scoring the pain; no pain (0), mild pain (1-2), moderate to severe pain (3-6), very severe pain (7-9) and worst pain possible (10). After the treatment on the first day, each patient received a pain diary to write down their pain level with the same scale at the following time-points: 4hours, 1, 2, 3, 4, 5, 6, 7 days after instrumentation. For the assessment of pain after canal obturation, each patient received a phone call and was asked to tell his/her pain score a day after treatment.

2.4.3. Analgesic intake

Patients were also requested to record the date and time of their analgesic intake on the diary.

2.5. Statistical analysis

Chi-square test was used to evaluate the data relating to baseline characteristics of the included study participants and analgesic intake ratio. Two statistical methods were used to assess the predictor of postoperative pain; univariate multiple regression analysis and logistic regression analysis. Post-operative NRS was dichotomized into absent/mild (0–2)

and moderate/intense (responses 3–10) for a logistic regression analysis. Mann-Whitney u test was used to evaluate the analgesic intake number of the two treatment groups. Difference between the groups were considered significant at $P<0.05$.

III. Results

3.1. Demographics

Initially 172 participants and 184 teeth which met the inclusion criteria were enrolled.

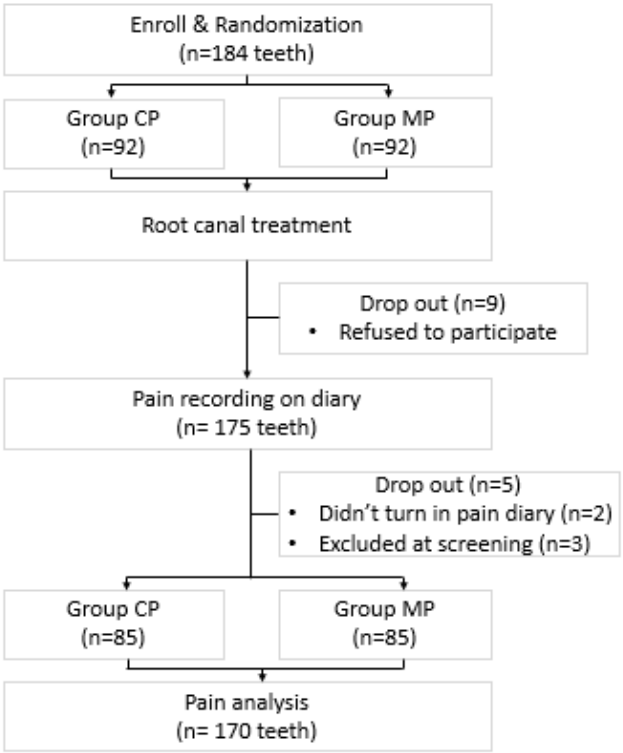

Figure 1. Flow chart of clinical trial procedures

Nine patients retracted enrollment and did not record pain diary. Two patients did not turn in their pain diary. Three cases were excluded at screening: one patient got two teeth treated at the same day, and one case was failed to negotiate to the apex. Thus eleven patients and fourteen teeth got excluded. Eventually 161 patients and 170 teeth were included for analysis.

The demographic characteristics did not show any significant difference between the two treatment groups except mean age and presence of sinus tract (Table 1).

Table1. Baseline demographic and clinical features distribution of patients

Factors		CP	MP	Total
Mean age		46.6±17.5	52.5±18.2	49.5±18.1
Gender	Female	49 (57.6%)	49 (57.6%)	98 (57.6%)
	Male	36 (42.4%)	36 (42.4%)	72 (42.4%)
Preoperative pain	Acceptable (NRS≤2)	65 (76.5%)	54 (63.5%)	119 (70%)
	Non-acceptable (NRS≥3)	20 (23.5%)	31 (36.5%)	51 (30%)
Location	Maxilla	48 (56.5%)	49 (57.6%)	97 (57.1%)
	Mandible	37 (43.5%)	36 (42.4%)	73 (42.9%)
Tooth	Anterior	17 (20%)	16 (18.8%)	33 (19.4%)
	Premolar	18 (21.2%)	26 (30.6%)	44 (25.9%)
	Molar	50 (58.8%)	43 (50.6%)	93 (54.7%)
Percussion pain	No	47 (55.3%)	46 (54.8%)	93 (55%)
	Yes	38 (44.7%)	38 (45.2%)	76 (45%)
Pulp	Pulpitis	37 (43.5%)	40 (47.1%)	77 (45.3%)
	Necrosis	48 (56.5%)	45 (52.9%)	93 (54.7%)
Sinus tract	Absence	66 (77.6%)	79 (92.9%)	145 (85.3%)

	Presence	19 (22.4%)	6 (7.1%)	25 (14.7%)
PAI index	≤2	34 (40%)	45 (52.9%)	79 (46.5%)
	≥3	51 (60%)	40 (47.1%)	91 (53.5%)

3.2. Mean post-endodontic pain score after first visit and canal obturation

Table 2 and Figure 2 present the mean postoperative NRS at each time point.

Table 2. Mean of Post-endodontic pain of group CP and MP.

	Group CP		Group MP	
Time	Mean	SD	Mean	SD
PreOP	1.83	2.49	2.24	2.76
4h	1.41	1.49	1.95	1.90
Day 1	1.23	1.31	1.70	1.96
Day 2	0.92	1.17	1.17	1.46
Day 3	0.67	0.96	0.94	1.36
Day 4	0.61	0.93	0.65	1.18
Day 5	0.47	0.90	0.42	0.94
Day 6	0.43	0.83	0.42	0.96
Day 7	0.34	0.74	0.40	1.09
CF	1.22	1.65	1.03	1.61

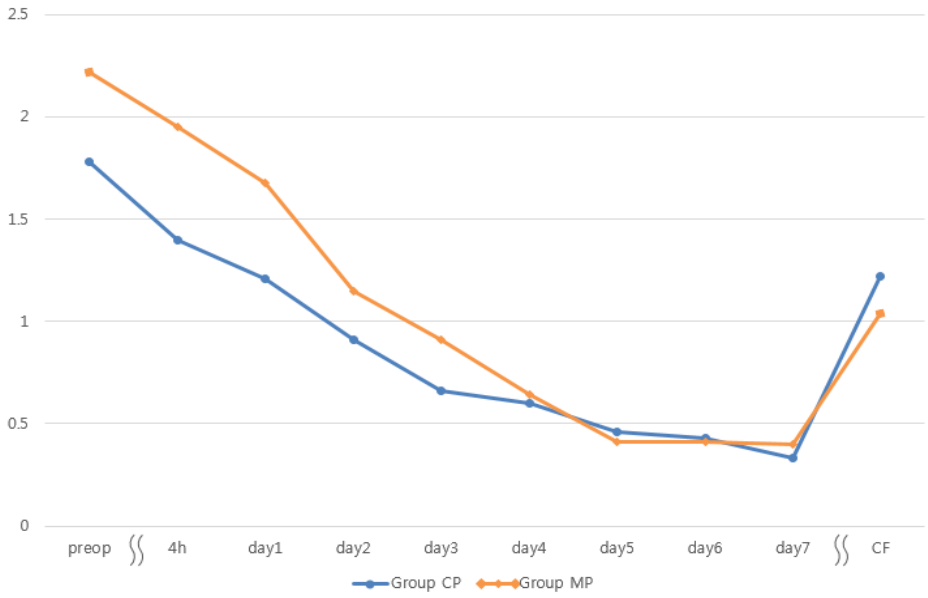

Figure 2. Mean NRS of treatment group CP and MP

3.3. Predictors of post-endodontic pain after instrumentation

3.3.1 Maximum pain score after instrumentation

Multiple regression analysis showed that there was no significant difference between treatment groups on maximum post-endodontic pain score (p=0.076). Preoperative NRS score significantly affected maximum NRS after first treatment (p<.001). Teeth with

higher preoperative NRS score showed greater pain scores.

Table 3. Parameters for NRS after instrumentation, multiple regression analysis.

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	1.114	0.349	3.193	0.002
MP group	0.447	0.250	1.787	0.076
Mn.	0.110	0.252	0.437	0.663
Pulpitis	0.424	0.314	1.350	0.179
PAI 3-5	-0.151	0.307	-0.492	0.624
Pre-Op NRS	0.277	0.051	5.482	<0.001

3.3.2 Incidence of unacceptable pain after instrumentation

The logistic regression analysis showed that there was no significant difference between treatment groups MP and CP (p=0.084). However, tooth type (p=0.033) and preoperative NRS score (p<0.001) had significant influence on the postoperative non-acceptable pain incidence. Premolars showed 5.26 times as high incidence as anterior teeth.

Table 4. Incidence of NRS score ≥3 after canal preparation, logistic regression analysis.

Parameter	O.R	Standard Error	t Value	Pr > |t|
CP group	ref.			
MP group	2.03	0.91	4.52	0.084
Age	0.98	0.96	1.01	0.160
Male	ref.			
Female	1.61	0.71	3.66	0.252
Mx.	ref.			
Mn.	0.81	0.36	1.84	0.621
Ant.	ref.			
Premolar	5.26	1.15	24.08	0.033
Molar	3.92	0.92	16.79	0.065
Pre-Op NRS	1.41	1.19	1.66	<0.001
Per(-)	ref.			
Per(+)	0.58	0.25	1.37	0.213
Sinus tr.(-)	ref.			
Sinus tr.(+)	0.70	0.18	2.70	0.601
Necrotic	ref.			

pulpitis	0.59	0.21	1.71	0.334
PAI 1-2	ref.			
PAI 3-5	0.45	0.16	1.21	0.112

3.4. Predictors of pain after canal obturation

3.4.1 Maximum pain score after canal obturation

There was no significant difference between treatment groups (p=0.454) on pain after canal obturation. Preoperative NRS score (p=.004) and pulp state (p=0.033) significantly affected pain after canal obturation. Teeth with higher preoperative NRS score showed greater pain scores. Pulpitis state pulp showed greater pain than necrotic pulp. Mean NRS of necrotic pulp is 0.53, compared to 1.63 of pulpitis.

Table 5. Parameters for maximum NRS after canal obturation, multiple regression analysis.

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	0.998	0.511	1.952	0.053
Age	-0.013	0.006	-1.959	0.052
Premolar	0.497	0.353	1.407	0.161

Molar	0.264	0.315	0.838	0.403
Per(+)	0.207	0.245	0.846	0.399
Pulpitis	0.639	0.297	2.150	0.033
PAI 3-5	-0.341	0.289	-1.179	0.240
Pre-Op NRS	0.145	0.050	2.918	0.004

3.4.2 Incidence of unacceptable pain after canal obturation

There was no significant difference between treatment groups MP and CP (p=0.158). Preoperative NRS score was a significant factor (p=0.015). Teeth with higher preoperative NRS score showed greater incidence.

Table 6. Incidence of NRS score ≥3 after canal obturation, logistic regression analysis

Parameter	O.R	Standard Error	t Value	Pr > |t|
CP group	ref.			
MP group	0.47	0.16	1.34	0.158
Age	0.98	0.95	1.01	0.128
Male	ref.			

Female	2.12	0.73	6.21	0.169
Mx.	ref.			
Mn.	0.80	0.28	2.29	0.684
Ant.	ref.			
Premolar	7.17	0.71	72.21	0.095
Molar	2.64	0.28	24.83	0.396
Pre-Op NRS	1.29	1.05	1.58	0.015
Per(-)	ref.			
Per(+)	2.00	0.67	5.99	0.215
Sinus tr.(-)	ref.			
Sinus tr.(+)	0.14	0.01	1.75	0.127
Necrotic	ref.			
pulpitis	2.57	0.67	9.85	0.168
PAI 1-2	ref.			
PAI 3-5	0.81	0.22	3.00	0.749

3.5. Analgesic intake of the two treatment groups

3.5.1 Analgesic intake ratio

The analgesic intake ratio did not show significant difference between the two treatment groups (p=0.074).

Table 7. Analgesic intake of the two treatment groups, chi square test.

Factor	Group		
	CP, n	MP, n	p
Analgesic intake			
No	74	65	.074
Yes	11(12.9%)	20(23.%5)	

3.5.2 Number of analgesic intake

Number of analgesic intake did not show significant difference between the two treatment groups (p=0.085).

Table 8. Number of analgesic intake, Mann-Whitney U test

	Group CP		Group MP			
	Mean	SD	Mean	SD	Z	P
No. of intake (whole group)	0.44	1.56	0.57	1.41	-1.721	.085

No. of intake (intake 'yes')	3.45	3.04	2.5	1.96	-.475	.635

IV. Discussion

Not only is the successful healing of the apical tissue after treatment, but also the successful pain management during root canal treatment is a main concern for clinicians. Postendodontic pain is known to be occurred by the extrusion of debris or irrigant, bacteria and remaining pulp tissue. Preoperative symptoms, pulp state, gender, tooth location etc. are reported as possible factors responsible for postendodontic pain (Torabinejad et al. 1988). But there are few studies about the postendodontic pain of minimally invasive endodontics.

Conventional preparation using Protaper, or Protaper Gold left large untreated areas in root canals (Paqué et al. 2009, Gagliardi et al. 2015). Therefore, chemical cleaning is important for disinfection of the root canal system. In addition, the TruNatomy system was developed to preserve more dentin during canal preparation, so the question was raised about the cleaning efficacy of the root canal system. Because of the possibility of insufficient cleaning with MP, we added PUI and CH medicament adjunctively for enhanced chemical cleaning.

The UI system we used was the Endosonic Blue, which is composed of a portable ultrasonic device and a size 15, 0.02-tapered, nickel-titanium (Ni-Ti) file. The file can penetrate deep into the minimally prepared root canal. Currently a standardized protocol is lacking for the UI (Van der Sluis et al. 2007), and the time and numbers of cycle for the UI varied: for less than 10 seconds to more than 90 seconds per cycle and for 1 to more than 3 cycles (Căpută et al. 2019). In this study we applied ultrasonic for 15seconds per cycle, 3 cycles per visit.

The effect of CH in eliminating bacteria from human root canal is not clear (Sathorn et al. 2007). However, a recent study showed that teeth treated with CH as the intracanal medicament present a greater reduction of mean LPS independent of the irrigant solution (Bedran et al. 2020).

The results of this study suggest that MP with PUI and CH did not provoke greater level of postoperative pain compared to CP. In this study, maximum pain scores were used for the analysis rather than the average of the measured values. Maximum pain scores represent the intensity of pain better, and the effect of analgesic could also be minimized. For the analysis of unacceptable pain, we set NRS=3 as the border because NRS=3 was the base score for moderate pain that distracts patient from their daily lives and requires analgesics. None of the results about the maximum pain after the instrumentation, and canal obturation, the incidence of unacceptable pain, analgesic intake ratio and number of analgesic intake showed significant difference between the

two treatment groups, CP and MP.

The main interest of this study was to compare the incidence and intensity of postoperative pain in patients undergoing treatment with the two different methods. However, since pain is a multifactorial phenomenon, we tried to find prognostic factors related to post-operative pain with a regression analysis. Both maximum pain score and the incidence of unacceptable pain were significantly affected by preoperative pain score. These findings are in agreement with previous studies (Siqueira et al. 2002, Glennon et al. 2004).

Although the incidence of unacceptable pain was similar in premolar (34.1%) and molar teeth (34.4%), the significant difference was found only between anterior and premolar teeth. It seems that the relatively high preoperative pain score in the molar teeth affected the statistical results in this study.

The maximum pain score after canal obturation was greater in teeth with pulpitis compared to teeth with necrotic pulp ($p=0.033$), but the incidence of unacceptable pain showed no significant difference. This was in disagreement with Albashaireh and Alnegrish (1998) and Genet et al. (1987) who reported greater incidence of post-obturation pain in necrotic teeth. However, only teeth with no tenderness to percussion were included in the former study, and the results of the latter was confined only to teeth with necrotic pulp ‘with preoperative pain’. In our study, mean preoperative NRS score of teeth with pulpitis (3.03) was higher than that of teeth with necrotic pulp (1.21). This

difference might have affected the results.

The ratio of patient who took analgesics were 23.5% for MP group and 12.9% for CP group, and the average intake number was 2.5 for MP group and 3.45 of CP group, both results showing no significant difference ($p>0.05$). Restricting analgesic intake could have made it possible to analyze the pure effect of treatment protocols better, but it was unavailable due to ethic issues.

V. Conclusion

Within the limitations of this study, the post-endodontic pain of MP with TruNatomy, UI, CH and calcium silicate based sealer did not differ from that of CP. Preoperative pain score, tooth type and pulp state were determined to be prognostic factors for postoperative pain.

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Abstract (In Korean)

최소침습적 근관확대와 칼슘실리케이트 실러를 이용한 근관 치료의 술후 동통
: 무작위 임상 연구

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본 무작위 임상연구의 목적은 두가지 근관 확대와 세정 방법: ProTaper Gold 시스템을 이용한 전통적인 방법(CP)과 TruNatomy 시스템, 초음파 세척(UI) 그리고 수산화 칼슘(CH) 첩약을 이용한 최소침습적 방법(MP)을 이용한 근관치료에서 술후 동통의 발생률 및 그 강도를 비교하는 것이다.

총 172명의 환자와 184치아가 연구에 등록되었다. 모든 치아의 근관치료는 2회 이상에 걸쳐 시행되었다. CP 그룹에서 근관 충전은 AH plus와 연속가압충전을 통하여, MP 그룹에서는 Endoseal TCS를 이용한 실러 기반 충전법을 통하여 이루어졌다.

첫 치료 이후 환자들은 7일간 동통 정도를 숫자(Numeric rating scale)로 기록하고 진통제 복용 시간을 기록하는 통증기록지를 받았다. 근관충전 이후의 동통 정도는 연구원이 치료 완료 하루 후에 전화로 조사하였다.

최종적으로 161명의 환자의 170개의 치아에 대한 분석이 이루어졌다. 각 치료 그룹별 치아는 85개가 포함되었다. 첫 내원 이후 통증을 기록한 기간 중 최대 통증값과 근관충전 후 통증값, 중등도 이상의 통증 발생률, 진통제 복용 여부와 횟수를 분석하였다. 최대 통증값이나 중등도 이상의 통증 발생률, 진통제 복용 여부와 횟수 모두 두 치료 그룹에서 유의한 차이가 나지 않았다 ($P<0.05$). 두 치료 그룹 간에 차이는 없었으나, 술전 통증 점수가 높을수록 술후 통증도 높아지는 양상이 있었다.

본 연구의 결과로 볼 때 TruNatomy, UI, CH와 칼슘실리케이트 기반 실러를 사용해 시행한 최소침습적 근관치료는 전통적인 근관치료와 비교하여 유사한 정도의 술후 동통을 일으키는 것으로 보인다.

핵심 되는 말 : 최소침습 근관치료; 근관치료 후 동통; Trunatomy, 칼슘실리케이트 계통 실러; Endoseal TCS