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ORIGINAL ARTICLE/ARTICOLO ORIGINALE

Analysis of operator variability in standardized root canal preparation with Ni—Ti instruments

Analisi della variabile operatore nella preparazione canalare standardizzata con strumenti AL Ni—Ti

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KEYWORDS
Operator variability;
Experience;
NiTi;
Shaping;
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Summary
Objectives: The aim of this study is to assess the influence of the operator variability during the preparation of standard resin blocks and the learning process with Ni—Ti instruments, the null hypothesis being that there are no significant differences regarding dentin removal, variation of the angle and radius of curvature, centering of the preparation, and time required by operator with different clinical experience.
Materials and methods: 100 standard resin blocks were used for this study. The blocks were divided into 4 groups of 25, and each group was assigned to a different operator. Operators 1 and 2 were 4th year DDS undergraduate students that had never performed endodontic treatments and as such could be considered as inexperienced operators. Operators 3 and 4 were 2 clinicians with 10 years experience and that were familiar with endodontic treatments and instrumentation (experienced operators). Many parameters were measured and compared.
Result: Differences could be detected between the 2 different level of clinical experience.
Conclusions: Under the experimental conditions of this study, experience of the operators can be considered as a crucial factor when all the other parameters are kept standard. In conclusion the null-hypothesis has to be rejected. Statistically significant differences exist in dentin removal, in the variation of the degree of curvature, in the centering of the preparation and in the time needed for the preparation when operators with different clinical experience where tested.

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Variabilità operatore;
Esperienza;
NiTi;
Sagomatura;
Trattamento endodontico.

Riassunto
Obiettivi: Scopo di questo studio è stato quello di valutare l'influenza della variabile operatore e il processo di apprendimento, nella preparazione canalare di blocchetti di resina standard mediante l'utilizzo di sistematica al Ni—Ti testando quindi l'ipotesi nulla che non vi siano differenze significative nella rimozione di dentina, nella variazione dell'angolo di curvatura, nella centratura della preparazione e nella quantità di tempo necessaria alla preparazione impiegando operatori con esperienza clinica differente.
Materiali e metodi: Sono stati utilizzati 100 blocchetti in resina standard. I blocchetti sono stati quindi suddivisi in 4 gruppi da 25 elementi ciascuno e ogni gruppo è stato strumentato da un operatore differente. Gli operatori 1e 2 erano 2 studenti del IV anno di odontoiatria che non avevano mai effettuato terapie canalari (e che quindi potevano essere considerati operatori inesperti), gli operatori 5 e 6 invece 2 clinici che lavoravano da almeno 10 anni e quindi familiari con le tecniche e con gli strumenti endodontici (operatori esperti). Gli operatori sono stati confrontati su vari parametri.
Risultati: Ci sono differenze tra i 4 operatori
Conclusioni: Dai dati ottenuti si evince che quando gli altri fattori, come la geometria canalare, la sequenza degli strumenti e la velocità di rotazione sono mantenuti costanti, l'abilità dell'operatore sembra essere un importante fattore clinico nell'ottenimento di buone preparazioni canalari. Con queste condizioni, i risultati del presente studio suggeriscono che l'esperienza dell'operatore costituisce una variabile prioritaria e un parametro di elevata predicibilità della qualità della strumentazione canalare quando gli altri parametri rimangono identici.

Introduction

The introduction of nickel—titanium rotary instrumentation has allowed to improve the quality of root canal shaping; this aspect is highlighted in curved canals that often represent the proofing grounds for endodontic instrumentation and techniques. The shaping time has been drastically reduced with regards to the time required to perform manual shaping. In a comparative study that tested different rotary systems and manual reamers and files, the results showed a significant reduction in treatment time when using rotary nickel titanium instruments.[1]

The main advantage cited in published studies is the ability to produce good shapes independently of the operator. Practically, they promise the clinics to diminish working time and reduce the variability related to operator experience and clinical ability.

In reality, many studies assessed the influence of the operator. Mandel,[2] has analyzed the effects of clinical experience on the fracture of Profiles by inexperienced students. They assessed using 25 resin blocks and highlighted 2 periods: a first period of apprenticeship that corresponds to 13 blocks during which the student learns the technique and the second ''application'' period during which the operator applies the technique to the ultimate 12 blocks getting better results than the first period. Mandel concludes that experience and being familiarized with the techniques are crucial to the predictable success of endodontic therapy.

In the same way, Mesgouez,[3] has taken into consideration the time required to prepare a resin block using nickel-titanium rotaries, showing it to be inversely proportional to the operator experience.

Yared and Barbakov[4,5] also have demonstrated the extent to which experience is important to minimize the incidence of fracture of endodontic instruments inside root canals that avoid complications. The same Yared[6] states in another study that using a NiTi rotary by an inexperienced operator is more secure when they operate at low torque setting thus avoiding fracture.

Baumann,[7] assessed the quality of shaping in relation to experience, by stating that experienced and non-experienced operators can achieve good results (with certain differences in favour of experienced operators) when using Ni—Ti instruments. From the review of the literature we can conclude that the experience of the operator is somehow a crucial factor in order to obtain good results when Ni—Ti instruments are employed. Manufacturers often state the opposite.

The aim of this study is to assess the influence of the operator variable during the preparation of standard resin blocks testing the null hypothesis that there are no significant differences regarding dentin removal, the variation of the angle and radius of curvature, the centering of the preparation, and the time required by operator different clinical experience.

Materials and methods

100 standard resin blocks (Sweden & Martina, Padova, Italia) were used for this study. This allowed to standardize canal length and anatomy, taper, angle and radius of curvature, material characteristics, and coronal and apical diameter. 10 blocks were randomly chosen and used to assess optically and radiographically the degree of standardization achieved. Then, the blocks were divided into 4 groups of 25, and each group was assigned to a different operator. Operators 1 and 2 were 4th year dentistry students that had never performed endodontic treatments and as such could be considered as inexperienced operators. Operators 3 and 4 were 2 clinicians with 10 years experience and that were familiar with

endodontic treatments and instrumentation (experienced operators).

Many parameters were measured such as time of preparation, angle of curvature, symmetry and centering of the preparation, quality of the preparation, broken or deformed instruments. Each block was numbered to analyze the quality of the preparation in relation to the evolution of experience. The latter was mainly valid for students.[2] Each set of instruments was used to prepare 7 blocks, and evaluated at the end of each preparation for fracture and deformation (4× magnification). An electric motor (Teknica, Dentsply Maillefer, Ballaigues, Switzerland) allowed for constant speed (300 rpm) and torque (80N/m). During shaping, irrigation was performed with water for lubrication and debris removal purposes. Hand and nickel titanium rotary instruments [M-Two, Sweden & Martina SPA, Due Carrare (PD) — Italia] were later used according to the following sequence [Fig. 1]: pathfinding with #10 K-file to the working length, preflaring with M-Two #10.04 for 15s also to working length followed by sequential use of M-Two #10.04, 15.05, 20.06 and 25.06 to working length.

Assuming that these blocks simulated a mesial root of a mandibular molar, 2 radiographs were performed on each block, one in the hypothetical buccal-lingual direction and the other in the mesio-distal direction. Radiographs were done using radiovisiography (Trophy) that allowed to generate digital radiographs (526 × 778 pixels). Standardization of radiographs was possible using a radiographic template that allowed for reproducible positioning and alignment of the blocks relatively to the x-ray source and sensor. It is made from 2 plexiglass slabs, with an embedding part allowing for precise and reproducible positioning of the blocks and make them solidary from the x-ray tube. The lower slab has a lodgment for the x-ray sensor and a support rod for the Rinn centering ring that is used for repositioning the x-ray tube that is stabilized using silicone (Provil Putty, Heraus-Kultzer) [Fig. 2]. The upper slab that fits perfectly the lower slab, has a lodgement for the plastic block.

A barium sulfate containing contrast liquid (Iopamiro 300, Bracco) is placed using an irrigating syringe inside the RCS to increase its opacity. Digital radiographs are analyzed using Scion Image Software (Shareware, NIH Image). This software allows for identifying root canal alterations (resin removal, root canal enlargement and transportation) by superposition of the original canal shape and the final canal shape. The perfect positioning of the images is possible thanks to the endodontic instrument placed on the upper slab of an

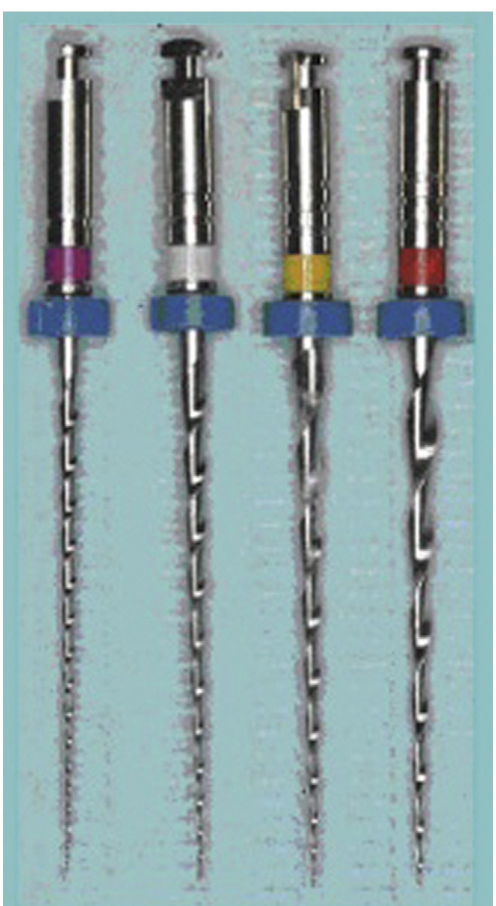

Figure 1 Sequence M-Two used.

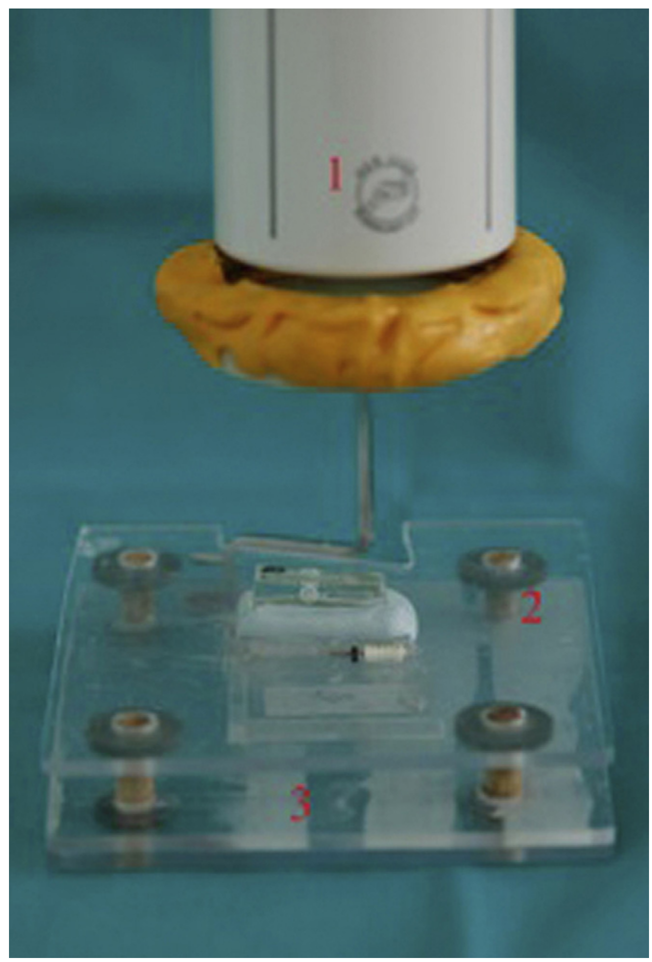

Figure 2 Radiographic template made from 2 plexiglass slabs, with an embedding part allowing for precise and reproducible positioning of the blocks and make them solidary from the x-ray tube. The lower slab has a lodgment for the x-ray sensor and a support rod for the Rinn centering ring that is used for repositioning the x-ray tube that is stabilized using silicone (Provil Putty, Heraus-Kultzer). The upper slab that fits perfectly the lower slab, has a lodgement for the plastic block.

endodontic instrument that appears in all radiographs. Since the dimension of the silicon stopper is known (1.5 mm), it also allows for calibration.

With regards to bucco-lingual images and according to Alodeh et al.[8] and Calberson et al.,[9] 5 points are taken into consideration: the canal orifice (O), the point located midways between the orifice and the starting point of the curvature (OH), the starting point of the curvature where the root canal deviates from the main axis of the coronal portion (BC), the apical point of the curvature where the axis of the coronal and apical portion of the canal meet (AC), and final point of the preparation (EP) [Fig. 3].

For the mesio-distal radiographs and as no references were available to identify points, 3 points were selected two of which are common with bucco-lingual radiographs: O, mid point (M), and EP. Fig. 3a shows root canal anatomy (bucco-lingually) before instrument, 3b after. 3c shows the super-imposition of the images. This last one was used for calculation of numerical data. Using the super-imposed image, thanks to the software, it was possible to calcolate:

- variation in the degree of curvature after instrumentation
- time needed for the preparation
- quantity of dentin (material) removed @ different level of the preparation
- presence of root canal alterations, such as zips and ledges
- broken instruments. In order to evaluate the influence of training on the assessed parameters, one month after the first trial low-experience operators were requested to prepare a second series of 15 resin blocks. The data from the second trial were compared with those from the last 15 blocks of the previous series. The data obtained were analyzed using SPSS software version 11.

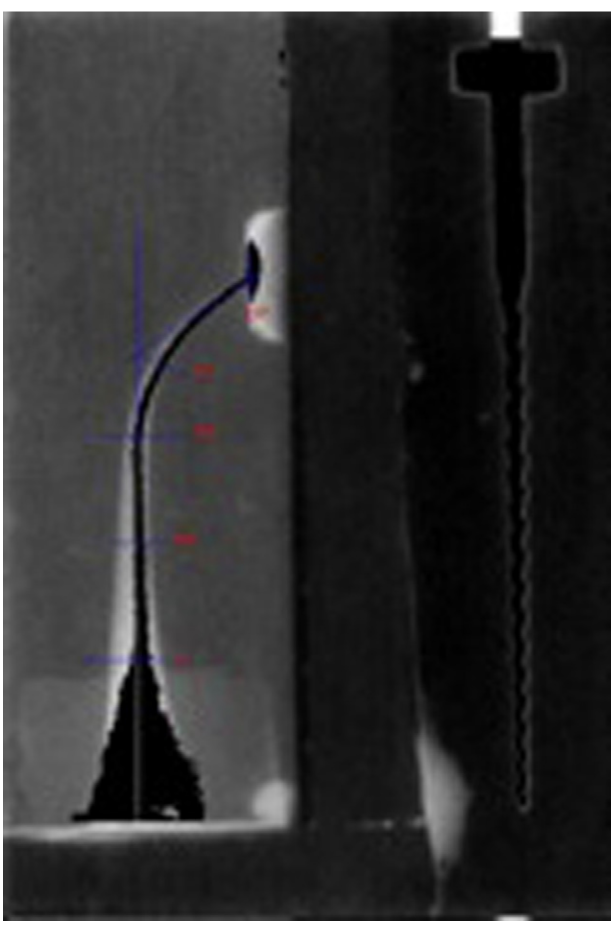

Figure 3 (a) Shows root canal anatomy (bucco-lingually) before instrument, (b) after. (c) Shows the super-imposition of the images.

Results

Variation in the degree of curvature Variation was calculated subtracting the original value of the angle of curvature 56.90, the same for all resin blocks to that after instrumentation The degree of curvature before and after instrumentation was calculated according to Weine's method. The initial degree of curvature was 56.90° (Table 1)

By applying the Repeated Measures Analysis of Variance (RMANOVA) it was assessed whether a learning process in handling the instruments (within subject factor) and the level of the operator's experience (between subject factors) had an influence on the variation of the curvature degree. The learning process did not have a significant influence on the assessed parameter for either experience level. Conversely, the operator experience appeared to have a significant influence on the change in curvature degree ($p < 0.001$). Particularly, the less experienced operators effected a significantly greater change in the degree of curvature

Table 1 Variation in the degree of curvature.

Blocchetto	Operator 1	Operator 2	Operator 3	Operator 4
1	3.42	2.13	0.25	3.47
2	0.44	5.33	2.18	2.09
3	2.55	4.58	1.46	0.63
4	0.44	6.53	2.37	1.51
5	1.59	6.85	0.19	2.91
6	2.63	1.05	2.37	1.09
7	1.63	0.92	1.88	0.30
8	3.06	1.29	2.55	1.53
9	0.75	4.27	1.17	0.87
10	1.83	5.97	2.51	1.64
11	4.96	4.28	1.45	0.59
12	3.27	1.08	0.40	2.76
13	1.69	3.09	2.83	1.40
14	1.59	6.77	2.85	1.19
15	3.43	1.61	3.76	1.29
16	0.99	6.87	0.13	0.89
17	2.22	5.10	2.43	0.58
18	5.53	2.68	2.12	2.53
19	2.71	3.26	0.12	1.85
20	5.32	3.32	2.16	2.03
21	0.92	1.09	2.04	1.46
22	3.37	4.62	1.61	0.81
23	3.00	0.83	2.80	2.39
24	2.86	6.00	1.67	0.87
25	1.92	1.91	1.88	1.81
MEDIA	2.48	3.66	1.81	1.54

Table 2 Time for instrumentation.

Operator	Experience	N	Mean	Std. Deviation	Significance $p < 0.05$
1	Low	25	98.3	7.5	a
2		25	97.5	16.4	a
3	High	25	71.3	2.1	b
4		25	66.3	4.8	b

Amount of removed material.

Time for instrumentation

The RMANOVA demonstrated that the level of experience significantly affected the time for instrumentation, with the more experienced operators being able to complete instrumentation in significantly less time (Table 2 $p < 0.05$).

Amount of removed material

The values regarding the amount of removed materials are given in table (Table 3a—d, Table 4a—d, Table 5a—d and Table 6a—d). The amount of the material removed by the differently experience operators was compared with the Mann—Whitney U test, as the data did not pass the normality test. The more experienced operators proved to remove significantly more material at point OH ($p < 0.05$). (Table 7).

Removal material OH point

A significantly lower amount of material was removed by the more trained operators group at point EP (Table 8 $p < 0.001$).

Removal material EP point

Also at point AC, the greater the experience the less was the amount of material removed (Table 9 $p < 0.05$).

Removal material AC point

Canal centering

At points O and EP, the significance of learning over repeated trials as well as of expertise in endodontics in the ability to maintain a centered preparation was assessed through the RMANOVA. Only the level of expertise in endodontics (between subject effect) appeared to significantly affect this parameter. Particularly, more trained operators demonstrated being able to produce significantly more centered preparations ($p < 0.05$).

Fractured and deformed instruments

Only one 15.05 instrument used by an experienced operator was fractured. No instruments deformations were reported.

Alterations of the canal shape

No abrupt changes to the canal shape were done by any operator.

Table 3 Values regarding the amount of removed materials.

(a) External side V-L

Blocchetto	O	OH	BC	AC	EP
1	0.63	0.54	0.23	0.33	0.08
2	0.45	0.30	0.11	0.22	0.22
3	0.41	0.22	0.04	0.12	0.19
4	0.45	0.19	0.04	0.04	0.11
5	0.19	0.30	0.11	0.14	0.04
6	0.22	0.07	0.07	0.05	0.07
7	0.38	0.34	0.11	0.17	0.11
8	0.56	0.37	0.11	0.17	0.11
9	0.37	0.34	0.11	0.14	0.04
10	0.11	0.07	0.04	0.14	0.07
11	0.11	0.11	0.07	0.05	0.04
12	0.22	0.11	0.07	0.14	0.04
13	0.15	0.22	0.15	0.17	0.15
14	0.30	0.19	0.04	0.08	0.04
15	0.22	0.15	0.04	0.08	0.04
16	0.22	0.34	0.07	0.14	0.11
17	0.26	0.26	0.11	0.15	0.11
18	0.22	0.30	0.12	0.22	0.11
19	0.38	0.26	0.08	0.14	0.11
20	0.38	0.26	0.08	0.14	0.11
21	0.22	0.30	0.15	0.20	0.07
22	0.38	0.22	0.07	0.17	0.11
23	0.38	0.26	0.04	0.16	0.11
24	0.38	0.26	0.11	0.18	0.11
25	0.38	0.30	0.07	0.17	0.11
MEDIA	0.32	0.25	0.09	0.15	0.10

(b) Internal side V-L

Blocchetto	O	OH	BC	AC	EP
1	0.31	0.15	0.12	0.04	0.08
2	0.60	0.45	0.49	0.22	0.15
3	0.64	0.45	0.49	0.25	0.07
4	0.56	0.34	0.60	0.39	0.11
5	0.53	0.30	0.30	0.04	0.04
6	0.60	0.41	0.56	0.24	0.04
7	0.45	0.30	0.34	0.11	0.07
8	0.34	0.15	0.37	0.20	0.07
9	0.30	0.30	0.37	0.17	0.07
10	0.56	0.34	0.22	0.11	0.07
11	0.56	0.41	0.49	0.25	0.04
12	0.56	0.41	0.56	0.22	0.07
13	0.53	0.26	0.34	0.15	0.07
14	0.41	0.26	0.56	0.30	0.12
15	0.45	0.34	0.45	0.15	0.04
16	0.49	0.15	0.26	0.08	0.04
17	0.41	0.19	0.26	0.12	0.07
18	0.45	0.19	0.30	0.07	0.04
19	0.39	0.34	0.41	0.15	0.07
20	0.39	0.34	0.41	0.15	0.07
21	0.34	0.19	0.34	0.08	0.04
22	0.34	0.22	0.40	0.12	0.04
23	0.41	0.26	0.34	0.27	0.11
24	0.41	0.30	0.41	0.08	0.07
25	0.38	0.22	0.26	0.08	0.04
MEDIA	0.46	0.29	0.39	0.16	0.07

Table 3 (*Continued*)

(c) External side M-D

Blocchetto	O	META′	EP
1	0.53	0.19	0.07
2	0.64	0.27	0.11
3	0.56	0.15	0.07
4	0.67	0.34	0.04
5	0.45	0.19	0.07
6	0.34	0.11	0.04
7	0.45	0.11	0.04
8	0.34	0.11	0.07
9	0.38	0.11	0.07
10	0.60	0.22	0.07
11	0.22	0.15	0.07
12	0.41	0.19	0.07
13	0.34	0.19	0.04
14	0.38	0.11	0.04
15	0.38	0.19	0.07
16	0.45	0.07	0.04
17	0.19	0.11	0.04
18	0.38	0.15	0.07
19	0.30	0.11	0.07
20	0.28	0.11	0.07
21	0.15	0.11	0.07
22	0.34	0.15	0.04
23	0.38	0.15	0.04
24	0.30	0.11	0.04
25	0.34	0.11	0.04
MEDIA	0.39	0.15	0.06

(d) Internal side M-D

Blocchetto	O	META′	EP
1	0.15	0.04	0.04
2	0.19	0.11	0.15
3	0.22	0.11	0.22
4	0.07	0.07	0.04
5	0.15	0.08	0.07
6	0.15	0.07	0.04
7	0.22	0.15	0.11
8	0.19	0.19	0.04
9	0.30	0.22	0.04
10	0.04	0.07	0.07
11	0.15	0.07	0.07
12	0.11	0.07	0.07
13	0.11	0.11	0.04
14	0.11	0.11	0.04
15	0.22	0.07	0.04
16	0.07	0.19	0.11
17	0.15	0.15	0.04
18	0.07	0.04	0.04
19	0.07	0.11	0.11
20	0.19	0.11	0.07
21	0.11	0.11	0.04
22	0.07	0.07	0.07
23	0.07	0.11	0.07
24	0.15	0.11	0.07
25	0.11	0.04	0.07
MEDIA	0.14	0.10	0.07

Table 4 Values regarding the amount of removed materials.

(a) External side V-L

Blocchetto	O	OH	BC	AC	EP
1	0.38	0.34	0.04	0.17	0.19
2	0.23	0.19	0.04	0.17	0.08
3	0.27	0.15	0.08	0.14	0.12
4	0.33	0.18	0.07	0.10	0.11
5	0.26	0.19	0.10	0.17	0.19
6	0.19	0.11	0.11	0.11	0.11
7	0.19	0.15	0.07	0.14	0.11
8	0.19	0.19	0.07	0.11	0.13
9	0.22	0.15	0.04	0.14	0.11
10	0.11	0.11	0.11	0.12	0.11
11	0.26	0.15	0.07	0.12	0.07
12	0.30	0.15	0.07	0.08	0.11
13	0.26	0.26	0.11	0.12	0.15
14	0.22	0.11	0.07	0.17	0.07
15	0.26	0.26	0.11	0.14	0.11
16	0.26	0.22	0.07	0.11	0.07
17	0.22	0.22	0.07	0.12	0.11
18	0.22	0.26	0.11	0.17	0.15
19	0.22	0.19	0.11	0.17	0.15
20	0.22	0.19	0.07	0.14	0.15
21	0.22	0.19	0.04	0.19	0.15
22	0.15	0.22	0.07	0.12	0.15
23	0.22	0.22	0.07	0.17	0.11
24	0.19	0.19	0.07	0.14	0.11
25	0.22	0.22	0.04	0.10	0.15
MEDIA	0.23	0.19	0.08	0.14	0.12

(b) Internal side V-L

Blocchetto	O	OH	BC	AC	EP
1	0.60	0.34	0.34	0.12	0.04
2	0.58	0.19	0.27	0.09	0.08
3	0.46	0.23	0.31	0.12	0.08
4	0.40	0.29	0.26	0.16	0.07
5	0.49	0.22	0.22	0.04	0.07
6	0.62	0.52	0.56	0.30	0.11
7	0.53	0.30	0.26	0.04	0.09
8	0.49	0.34	0.38	0.11	0.07
9	0.56	0.27	0.30	0.17	0.07
10	0.67	0.41	0.41	0.25	0.11
11	0.49	0.26	0.37	0.25	0.11
12	0.38	0.22	0.30	0.25	0.11
13	0.38	0.15	0.26	0.08	0.07
14	0.49	0.37	0.38	0.17	0.07
15	0.38	0.26	0.26	0.17	0.07
16	0.45	0.22	0.30	0.15	0.08
17	0.38	0.22	0.26	0.12	0.07
18	0.45	0.22	0.26	0.08	0.07
19	0.45	0.27	0.30	0.11	0.11
20	0.38	0.22	0.34	0.12	0.11
21	0.45	0.26	0.30	0.15	0.07
22	0.38	0.26	0.38	0.34	0.15
23	0.45	0.20	0.30	0.20	0.07
24	0.50	0.30	0.30	0.17	0.07
25	0.49	0.26	0.34	0.22	0.04
MEDIA	0.48	0.27	0.32	0.16	0.08

Table 4 (*Continued*)

(c) External side M-D

Blocchetto	O	META′	EP
1	0.34	0.18	0.04
2	0.45	0.22	0.07
3	0.45	0.12	0.04
4	0.53	0.07	0.04
5	0.41	0.07	0.04
6	0.45	0.11	0.04
7	0.53	0.19	0.04
8	0.53	0.22	0.07
9	0.34	0.11	0.04
10	0.45	0.15	0.04
11	0.26	0.15	0.04
12	0.30	0.15	0.07
13	0.38	0.07	0.04
14	0.34	0.15	0.04
15	0.53	0.19	0.04
16	0.34	0.04	0.04
17	0.41	0.15	0.04
18	0.34	0.04	0.04
19	0.45	0.19	0.04
20	0.34	0.22	0.04
21	0.49	0.07	0.04
22	0.22	0.15	0.04
23	0.50	0.15	0.07
24	0.47	0.19	0.04
25	0.47	0.07	0.04
MEDIA	0.41	0.14	0.04

(d) Internal side M-D

Blocchetto	O	META′	EP
1	0.19	0.04	0.11
2	0.26	0.07	0.04
3	0.11	0.07	0.04
4	0.15	0.07	0.07
5	0.19	0.04	0.04
6	0.19	0.04	0.07
7	0.07	0.04	0.07
8	0.11	0.08	0.04
9	0.22	0.07	0.07
10	0.15	0.04	0.04
11	0.30	0.07	0.04
12	0.30	0.07	0.07
13	0.22	0.11	0.17
14	0.19	0.07	0.04
15	0.07	0.07	0.07
16	0.22	0.15	0.11
17	0.11	0.15	0.15
18	0.26	0.19	0.07
19	0.19	0.07	0.07
20	0.26	0.06	0.15
21	0.22	0.19	0.13
22	0.11	0.11	0.07
23	0.07	0.19	0.07
24	0.04	0.07	0.07
25	0.07	0.19	0.07
MEDIA	0.17	0.09	0.08

Table 5 Values regarding the amount of removed materials.

(a) External side V-L

Blocchetto	O	OH	BC	AC	EP
1	0.38	0.19	0.04	0.08	0.05
2	0.45	0.15	0.04	0.04	0.04
3	0.26	0.07	0.04	0.08	0.07
4	0.37	0.07	0.04	0.08	0.07
5	0.55	0.19	0.07	0.11	0.07
6	0.37	0.15	0.04	0.07	0.04
7	0.67	0.34	0.04	0.08	0.04
8	0.37	0.15	0.04	0.07	0.04
9	0.37	0.15	0.04	0.04	0.04
10	0.56	0.11	0.04	0.05	0.11
11	0.45	0.15	0.07	0.04	0.04
12	0.45	0.19	0.04	0.04	0.04
13	0.26	0.04	0.04	0.05	0.07
14	0.45	0.15	0.07	0.05	0.04
15	0.49	0.11	0.07	0.04	0.04
16	0.49	0.15	0.07	0.04	0.04
17	0.41	0.15	0.04	0.04	0.04
18	0.60	0.22	0.04	0.04	0.04
19	0.64	0.22	0.04	0.11	0.07
20	0.45	0.26	0.04	0.12	0.07
21	0.22	0.07	0.04	0.11	0.04
22	0.41	0.26	0.04	0.04	0.04
23	0.41	0.30	0.11	0.04	0.04
24	0.30	0.19	0.07	0.16	0.07
25	0.30	0.15	0.07	0.07	0.04
MEDIA	0.43	0.17	0.05	0.07	0.05

(b) Internal side V-L

Blocchetto	O	OH	BC	AC	EP
1	0.34	0.26	0.38	0.04	0.07
2	0.30	0.26	0.49	0.25	0.17
3	0.47	0.45	0.41	0.17	0.04
4	0.30	0.41	0.45	0.14	0.04
5	0.22	0.26	0.45	0.11	0.04
6	0.26	0.30	0.41	0.17	0.11
7	0.04	0.07	0.30	0.04	0.07
8	0.30	0.37	0.49	0.20	0.11
9	0.34	0.37	0.34	0.17	0.04
10	0.30	0.34	0.45	0.25	0.04
11	0.26	0.26	0.37	0.17	0.11
12	0.22	0.26	0.34	0.16	0.04
13	0.45	0.45	0.41	0.08	0.04
14	0.26	0.30	0.41	0.22	0.07
15	0.34	0.45	0.50	0.29	0.04
16	0.37	0.34	0.41	0.19	0.11
17	0.37	0.45	0.41	0.22	0.07
18	0.34	0.37	0.50	0.39	0.11
19	0.34	0.34	0.52	0.29	0.04
20	0.37	0.37	0.37	0.16	0.07
21	0.34	0.30	0.26	0.05	0.07
22	0.41	0.41	0.52	0.30	0.15
23	0.19	0.19	0.19	0.05	0.07
24	0.37	0.30	0.26	0.08	0.07
25	0.25	0.37	0.34	0.08	0.04
MEDIA	0.31	0.33	0.40	0.17	0.07

Table 5 (*Continued*)

(c) External side M-D

Blocchetto	O	META′	EP
1	0.22	0.11	0.02
2	0.19	0.08	0.02
3	0.22	0.04	0.02
4	0.11	0.11	0.02
5	0.11	0.19	0.02
6	0.11	0.15	0.02
7	0.04	0.11	0.02
8	0.11	0.11	0.02
9	0.19	0.15	0.02
10	0.11	0.11	0.02
11	0.15	0.07	0.02
12	0.19	0.11	0.02
13	0.19	0.15	0.04
14	0.15	0.15	0.02
15	0.22	0.15	0.02
16	0.34	0.26	0.04
17	0.15	0.11	0.02
18	0.19	0.19	0.02
19	0.34	0.15	0.02
20	0.22	0.04	0.02
21	0.07	0.04	0.02
22	0.26	0.04	0.02
23	0.19	0.04	0.02
24	0.22	0.04	0.02
25	0.19	0.07	0.02
MEDIA	0.18	0.11	0.02

(d) Internal side M-D

Blocchetto	O	META′	EP
1	0.15	0.15	0.02
2	0.19	0.15	0.04
3	0.30	0.26	0.02
4	0.19	0.11	0.02
5	0.19	0.07	0.04
6	0.22	0.04	0.02
7	0.34	0.15	0.02
8	0.22	0.15	0.02
9	0.27	0.11	0.02
10	0.15	0.07	0.02
11	0.07	0.07	0.02
12	0.22	0.11	0.02
13	0.11	0.15	0.04
14	0.30	0.11	0.04
15	0.19	0.11	0.02
16	0.11	0.04	0.02
17	0.22	0.11	0.02
18	0.35	0.11	0.02
19	0.30	0.07	0.02
20	0.22	0.11	0.02
21	0.19	0.07	0.04
22	0.15	0.11	0.04
23	0.07	0.04	0.02
24	0.19	0.11	0.02
25	0.11	0.07	0.02
MEDIA	0.20	0.11	0.02

Table 6 Values regarding the amount of removed materials.

(a) External side V-L

Blocchetto	O	OH	BC	AC	EP
1	0.49	0.22	0.07	0.05	0.04
2	0.34	0.07	0.04	0.04	0.04
3	0.60	0.30	0.04	0.04	0.04
4	0.45	0.19	0.04	0.04	0.04
5	0.71	0.49	0.11	0.08	0.04
6	0.34	0.22	0.07	0.04	0.04
7	0.56	0.30	0.04	0.04	0.04
8	0.30	0.19	0.04	0.05	0.04
9	0.38	0.22	0.04	0.04	0.04
10	0.60	0.30	0.04	0.07	0.04
11	0.67	0.49	0.22	0.29	0.04
12	0.34	0.22	0.04	0.04	0.04
13	0.60	0.30	0.02	0.11	0.02
14	0.41	0.15	0.04	0.12	0.04
15	0.64	0.38	0.04	0.05	0.02
16	0.49	0.26	0.04	0.07	0.04
17	0.71	0.45	0.11	0.14	0.04
18	0.41	0.15	0.04	0.04	0.04
19	0.60	0.26	0.02	0.02	0.04
20	0.60	0.26	0.02	0.02	0.04
21	0.64	0.45	0.04	0.05	0.04
22	0.67	0.45	0.07	0.08	0.04
23	0.60	0.38	0.04	0.04	0.04
24	0.53	0.41	0.04	0.12	0.04
25	0.53	0.26	0.07	0.16	0.04
MEDIA	0.53	0.29	0.06	0.07	0.04

(b) Internal side V-L

Blocchetto	O	OH	BC	AC	EP
1	0.56	0.38	0.34	0.17	0.04
2	0.67	0.56	0.64	0.46	0.04
3	0.68	0.53	0.53	0.41	0.19
4	0.56	0.45	0.49	0.22	0.15
5	0.22	0.11	0.26	0.07	0.08
6	0.26	0.19	0.26	0.07	0.07
7	0.45	0.41	0.45	0.19	0.07
8	0.41	0.26	0.30	0.16	0.11
9	0.19	0.26	0.30	0.17	0.07
10	0.56	0.41	0.38	0.17	0.04
11	0.41	0.34	0.30	0.08	0.04
12	0.34	0.26	0.30	0.20	0.07
13	0.53	0.41	0.41	0.15	0.04
14	0.30	0.34	0.34	0.20	0.04
15	0.56	0.49	0.53	0.29	0.04
16	0.15	0.26	0.49	0.04	0.04
17	0.34	0.22	0.30	0.12	0.11
18	0.26	0.38	0.49	0.21	0.07
19	0.56	0.53	0.53	0.25	0.04
20	0.34	0.45	0.53	0.27	0.11
21	0.53	0.30	0.45	0.17	0.07
22	0.45	0.30	0.34	0.19	0.12
23	0.38	0.41	0.41	0.22	0.04
24	0.38	0.34	0.41	0.17	0.04
25	0.41	0.26	0.34	0.11	0.04
MEDIA	0.42	0.35	0.40	0.19	0.07

Table 6 (*Continued*)

(c) External side M-D

Blocchetto	O	META′	EP
1	0.19	0.22	0.02
2	0.15	0.15	0.02
3	0.19	0.19	0.02
4	0.22	0.22	0.02
5	0.22	0.15	0.04
6	0.11	0.19	0.02
7	0.19	0.19	0.02
8	0.22	0.15	0.02
9	0.11	0.22	0.02
10	0.22	0.15	0.02
11	0.26	0.11	0.02
12	0.26	0.22	0.02
13	0.15	0.07	0.02
14	0.11	0.07	0.02
15	0.15	0.11	0.02
16	0.26	0.22	0.02
17	0.15	0.19	0.02
18	0.15	0.15	0.02
19	0.19	0.17	0.02
20	0.15	0.19	0.02
21	0.30	0.26	0.02
22	0.22	0.11	0.02
23	0.11	0.15	0.02
24	0.19	0.11	0.02
25	0.17	0.11	0.02
MEDIA	0.19	0.16	0.02

(d) Internal side M-D

Blocchetto	O	META′	EP
1	0.45	0.19	0.02
2	0.41	0.19	0.02
3	0.30	0.07	0.02
4	0.30	0.04	0.02
5	0.22	0.11	0.02
6	0.26	0.04	0.02
7	0.34	0.07	0.02
8	0.11	0.07	0.02
9	0.11	0.04	0.02
10	0.38	0.11	0.02
11	0.30	0.19	0.02
12	0.07	0.04	0.02
13	0.41	0.11	0.02
14	0.19	0.04	0.02
15	0.30	0.07	0.02
16	0.07	0.04	0.02
17	0.22	0.15	0.02
18	0.11	0.04	0.04
19	0.26	0.19	0.02
20	0.30	0.11	0.02
21	0.34	0.07	0.02
22	0.38	0.07	0.02
23	0.30	0.11	0.02
24	0.19	0.11	0.02
25	0.22	0.11	0.02
MEDIA	0.26	0.10	0.02

Table 7 Removal material OH point.

Experience	N	Mean	Std. Deviation
Low	50	.50	.091
High	50	.57	.13

Table 8 Removal material EP point.

Experience	N	Mean	Std. Deviation
Low	50	.18	.055
High	50	.11	.038

Table 9 Removal material AC point.

Experience	N	Mean	Std. Deviation
Low	50	.30	.064
High	50	.25	.086

Evaluation of the learning process

A significant change occurred in the parameter "variation in the degree of curvature" between first and second series of data.

As the distribution was normal in both data series according to the Kolmogorov—Smirnov test, the Paired-Samples Test was applied. The difference between first and second series of data was significant ($p < 0.001$), Paired samples t-test, $p < 0.001$). The time needed to complete instrumentation was significantly reduced in the second series of test (Table 10).

As the distribution in the second series of data was not normal according to the Kolmogorov—Smirnov test, the Wilcoxon Signed Ranks Test was applied. The difference between

Table 10 Evaluation of the learning process (Time).

Time	*N*	Mean	Median	Std. Deviation	Minimum	Maximum
First series	30	92.77	94	8.661	73	106
Second series	30	75.73	75	2.753	72	82

Table 11 Evaluation of the learning process (EP).

Removal Point EP	*N*	Mean	Median	Std. Deviation	Minimum	Maximum
First series	30	.1793	.18	.05024	.08	.30
Second series	30	.0657	.06	.01524	.04	.09

Table 12 Evaluation of the learning process (AC).

Removal Point AC	*N*	Mean	Std. Deviation
First series	30	.3033	.05441
Second series	30	.2250	.07248

first and second series of data was significant ($p < 0.001$). Wilcoxon Signed Ranks Test, $p < 0.001$). Furthermore, a significantly lower amount of material was removed in the second series of tests at EP (Table 11).

As the distribution in the second series of data was not normal according to the Kolmogorov—Smirnov test, the Wilcoxon Signed Ranks Test was applied. The difference between first and second series of data was significant ($p < 0.001$). Wilcoxon Signed Ranks Test, $p < 0.001$) AC (Table 12).

As the distribution was normal in both data series according to the Kolmogorov—Smirnov test, the Paired-Samples Test was applied. The difference between first and second series of data was significant ($p < 0.001$), Paired Samples t-test ($p < 0.001$), and OH (Table 13).

As the distribution was normal in both data series according to the Kolmogorov—Smirnov test, the Paired-Samples Test was applied. The difference between first and second series of data was significant ($p < 0.001$), Paired Samples t-test, $p < 0.001$).

In the second trial the ability of the operators to maintain a centered preparation was significantly increased both at EP (Table 14).

As the distribution in the second series of data was not normal according to the Kolmogorov—Smirnov test, the Wilcoxon Signed Ranks Test was applied. The difference between first and second series of data was significant ($p < 0.001$). Wilcoxon Signed Ranks Test, $p < 0.001$) and O (Table 15).

As the distribution was normal in both data series according to the Kolmogorov—Smirnov test, the Paired-Samples Test was applied. The difference between first and second series of data was significant ($p = 0.037$), Paired Samples t-test, $p < 0.05$).

Table 13 Evaluation of the learning process (OH).

Removal Point OH	*N*	Mean	Std. Deviation
First series	30	.4750	.05400
Second series	30	.3973	.08170

Table 14 Evaluation of the learning process, second trial (EP).

Symmetry point EP	*N*	Mean	Median	Std. Deviation	Minimum	Maximum
First series	30	.0357	.35	.02772	.00	.10
Second series	30	.0115	.01	.00872	.00	.04

Table 15 Evaluation of the learning process, second trial (O).

Symmetry point O	Mean	*N*	Std. Deviation
First series	.1978	30	.09205
Second series	.1497	30	.06853

Discussion

Endodontic procedures evolved in the recent years, particularly after Ni—Ti spread into the market. This new kind of alloy allowed clinicians to reduce the total time needed for shaping and to obtain minimally invasive root canal preparations[10—13] with highly predictable results. Most of the Manufacturers affirm that the point O experience of the operator is no more an important factor when using Ni—Ti as it was before with stainless steel and manual preparations; being these new instruments capable of giving good preparation independently from the operator. The main purpose of the present study was in fact to analyze the "operator variability": for this reason we tried to standardize all the other variables. As a matter of fact resin blocks were used instead of natural teeth: this on one hand is a big difference with respect to the clinical conditions (and so the behaviour of the instrument might be different) but on the other hand guarantees a high degree of standardization (same working length, degree of curvature, anatomy). Nevertheless resin blocks are more difficult and instruments are more prone to fracture than when used in clinical conditions.[14,15] Anyhow only one instrument separation occurred. It was a 15.05 (on block number 21) probably due to cyclic fatigue of the instrument (6 canals already prepared by that instrument) and to a decrease in the attention of the experienced operator. Separation occurred in the apical portion, for a total length of the separated instrument of 1.5 mm.

As demonstrated by other studies[16] resin blocks represent a valid model for experimental projects regarding Ni—Ti instruments. In order to make it clear that all resin blocks were really identical, 10 blocks were casually chosen and radiographed (mesio-distally and bucco-lingually). Also working length, angle and degree of curvature were calculated using Weine's method.[17,18] The data obtained demonstrated that all the resin blocks were identical, so we speculated that all 100 blocks could be identical.

M2 instruments (VDW, Sweden & Martina SPA, Due Carrare (PD) - Italia) were used in this study. These instruments have two blades with a non working tip in order to reduce the residual core (anima residua) and increase the flexibility (Figs. 4 and 5).

The method for radiographic analyses used in this study[19] allows, in a simple and repeatable way, to compare the images of the root canal before and after the instrumentation, thus obtaining a quantitative analyses of the areas removed by the instrumentation. The images can also be enlarged using the software allowing for a more precise evaluation.

In the present study 4 different operators were evaluated. Operator 1 and 2 were undergraduate students, at their first preparation with Ni—Ti instruments, while operator 3 and 4 were clinicians with respectively 5 and 10 yrs of clinical

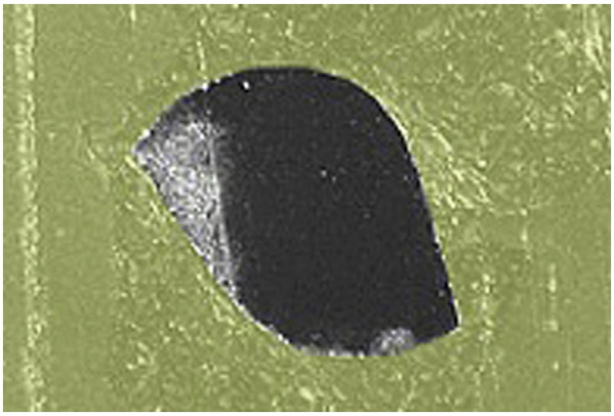

Figure 4 M-Two core.

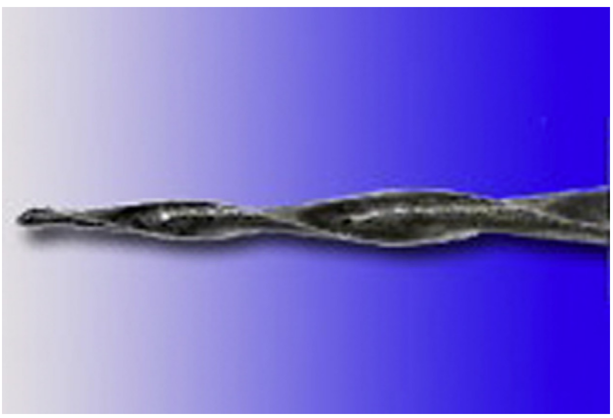

Figure 5 M-Two tip.

experience. This was done to put in evidence the difference in ''operator experience''. As a matter of fact a lot of differences were noted between the two groups of operators (1 and 2 vs 3 and 4). More in details, on one hand inexperienced operators tended to under-instrument the coronal area, and over-instrument the apical area. On the other hand experienced operators were more conservative at the apical area, preparing more at the coronal area (as if they were using a crown-down approach. Also this tends to demonstrate that experience was determinant for a correct shaping of the resin blocks.

The degree of curvature varied more for operators 1 and 2 than for operators 3 and 4: experienced operators were able to respect the original anatomy. Nevertheless the variation in the degree of curvature was lower than what reported in the literature. Petiette[20] noted a 14.44 variation when inexperienced operators were using manual stainless steel instruments. In the present study the average of the variation was 4.39.

Time needed for the preparation was not considered by the authors as a crucial factor. 2-3 minutes as a maximum were requested per each resin block. This is clinically acceptable as 25 minutes flushing of sodium hypochlorite are needed. Difference in the preparation was important. At the apical level inexperienced operators often over-instrument. This can clinically provoke the need for a filling with a bigger cone with respect to what done by experienced operators (0.18 vs 0.35).

Under the experimental conditions of this study, experience of the operators can be considered as a crucial factor when all the other parameters are kept standard. In conclusion the null-hypothesis has to be rejected. Statistically significant differences exist in dentin removal, in the variation of the degree of curvature, in the centering of the preparation and in the time needed for the preparation when operators with different clinical experience where tested. It is desirable to extend the present study to other Ni—Ti instruments and to other operators with different skills.

Conflict of interest

The authors have no conflict of interests to declare.

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