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CASE REPORTS

Next Generation Workflow for Apical Control in Endodontics: three case reports

ABSTRACT

Aim: *This report proposes a new, step-by-step workflow designed to safely manage the apical extent of root canal preparation. It utilizes advanced, motor-driven endodontic technology, specifically the enhanced Optimum Apical Stop (OAS2) function, to streamline and expedite traditional root canal procedures.*

Summary: *In this case series, three patients underwent endodontic treatment, using a motor-driven protocol with the Morita Tri Auto ZX2+ device (J. Morita Corp., Osaka, Japan) and its OAS2 function activated. Root canal shaping was initiated with VDW.ROTATE instruments (VDW GmbH, Munich, Germany), followed by refinement using ProTaper Ultimate F2 and F3 files (Dentsply Sirona, Charlotte, NC, USA), and obturation with conform fit gutta-percha cones. Postoperative assessments included clinical evaluation, periapical radiographs, and patient-reported outcomes at 1, 3, 6, and 12 months. Outcome measures included pain, swelling, tooth function, need for reintervention, adverse effects, and radiographic signs of periapical healing.*

Immediate postoperative radiographs showed high-quality apical preparation and obturation. At one-year follow-up, all three cases demonstrated complete symptom resolution and radiographic absence of periapical radiolucency.

Key learning points:

- *The OAS2 function allows controlled, minimal, and reproducible apical preparation.*
- *The workflow reduces chair-time and technical variability.*
- *Outcomes are successful regardless of operator experience.*
- *Radiographic healing and patient satisfaction are consistently achieved.*
- *The combined use of VDW.ROTATE and ProTaper Ultimate files supported effective and conservative canal shaping.*

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Introduction

The accurate maintenance of the apical limit during cleaning, shaping, and filling procedures has been closely associated with successful outcomes (1, 2). Accurate apical control during root canal preparation has been closely associated with reduced risk of complications such as over-instrumentation (3), extrusion of root canal filling materials beyond the apex, and damage to periapical tissues (4). During mechanical preparation, the three-dimensional shape and pathways of root canals are modified, which can cause slight variations in total canal length (5). Therefore, continuous monitoring of the working length (WL) is essential for preventing over-instrumentation and ensuring precise preparation (3, 6-9). Recent innovations in endodontic technology have provided innovative solutions to address the challenges of maintaining precise apical control (5). Endodontic motors with integrated electronic apex locator have been developed with the intention of simplifying and accelerating root canal treatment (6). These advanced systems provide numerous options for motions, angles, speeds, and apical control functions, while continuously monitoring and maintaining the apical limit during the mechanical preparation (10). This precision minimizes the risk of over-instrumentation and associated complications, fostering predictable treatment outcomes (1, 2). One useful apical function is the auto apical reverse technology (AAR) which automatically stops and reverses the rotation upon reaching the specified apical limit (6, 11, 12). This function has been deeply tested and its precision have been demonstrated ex-vivo on several endodontic motors (6, 10, 13). A recent innovation is the improved version of the Optimum Apical Stop (OAS2) technology which automatically perform twice reciprocating rotations of ± 180° before stopping the motion at a pre-set apical level, disengaging the flutes of the endodontic instrument, thereby preventing jamming or tip lock.

A recent ex-vivo study evaluated the performance of two endodontic motors in controlling the apical extent of root canal preparation compared to the visual determination of WL (3). The findings demonstrated that OAS or AAR functions successfully prevented over-instrumentation, maintaining precise control over the apical extent. The original OAS system improved root canal preparation with controlled reversing movements to prevent over-instrumentation, but depended on the cutting direction of the file, therefore limiting versatility. The OAS2 system advanced this concept with bidirectional reciprocation (+180°/-180°), enhancing control, safety, and compatibility with modern endodontic file systems. Despite these promising findings, to the best of our knowledge, no data exist on the reproducibility of WL measurements and the safety and success of the improved OAS2 function during routine clinical practice. Furthermore, no standardized protocol has been proposed for clinicians to incorporate this function into a simplified workflow to optimize shaping of the apical third.

Thus, this study aimed to introduce a protocol that leverages advanced motor-driven endodontic technology to simplify and accelerate traditional procedures by integrating an automated apical control function (i.e., OAS2) with contemporary instrumentation systems and compatible obturation materials. The purpose of this report is to propose a technique to lay the groundwork for future validation through more extensive research.

Case Report Informations

The present report was conducted in accordance with the 2020 Preferred Reporting Items for Case Reports in Endodontics (PRICE) guidelines (14).

Three consecutive patients who presented with the need for endodontic treatment were treated by an experienced endodontist in a private dental office in Milan, Italy, using a novel, simplified protocol for root canal shaping.

The affected teeth were a mandibular right first premolar (4.5; Case A; Figure 1), a maxillary right first molar (1.6; Case B; Figure 2), and an upper third molar (1.8; Case C; Figure 3). Case A was affected by "irreversible pulpitis", Case B was affected by "symptomatic apical periodontitis", while Case C was a previously initiated therapy (15).

Patient Evaluation

Upon obtaining informed consent for further evaluation, a review of the patients' non-contributory medical histories was conducted. The three referred patients were a 28-year-old female (A), a 32-year-old male (B), and a 52-year-old male.

Comprehensive oral and dental examinations were performed after gathering dental histories. The clinical examination revealed no abnormal extraoral findings, and all the neighboring teeth exhibited normal responses to cold [using 1,1,1,2-tetrafluoroethane (Endo-Ice; Coltène/Whaledent Inc, Cuyahoga Falls, OH)], percussion, and palpation tests, except for the tooth scheduled for treatment. Pre-operative periapical radiographs were taken using the long cone paralleling technique with a film holder and a beam-aiming radiographic unit (Nomad Pro 2; KavoKerr, Biberach, Germany) operating at 60 kV and 7 mA. Case A presented with pain and swelling in the area of interest, along with a positive, painful response to cold stimuli, and showed a slight enlargement of the periodontal ligament space without periapical radiolucency (Figures 1 and 3), confirming the diagnosis of "irreversible pulpitis." (15). Case C presented with pain and swelling in the area of interest, as well as a positive, painful response to cold stimuli. There was a slight enlargement of the periodontal ligament space without periapical radiolucency. Treatment was previously initiated; however, due to the complexity of the case, the patient was referred to the clinic to finalize the therapy. The tooth was temporarily sealed with Cavit (3M ESPE, Seefeld, Germany) by the previous dentist.

In contrast, case B, which presented a history of intermittent pain, pain on percussion, and a negative response to the cold test, showed slight periapical radiolucency in the mesial root (Figure 6), confirming the diagnosis of "symptomatic apical periodontitis" (15).

Procedure

The endodontic treatments were executed under local anesthesia (lidocaine 2% with epinephrine 1:100.000) with rubber dam isolation (Swedent, medium, Stockholm, Sweden). The whole procedure was conducted under magnification (Leica M320, Leica Microsystems, Wetzlar, Germany) at x8 magnification level. The access cavity was prepared with a high-speed round diamond bur (Komet Dental, Lemgo, Germany) and refined using an ultrasonic tip Start-X #3 (Dentsply Sirona, York, PA, USA). Afterwards, root canal instrumentation was conducted using the Morita Tri Auto ZX2+ motor, featuring the apical stop function OAS2 technology.

Root canal instrumentation was performed with the Tri Auto ZX2+ motor, setting the apical function OAS2 and the optimum torque reverse (OTR) motion selecting the following parameters on the meter display: speed at 300 rpm, "auto start" on, "auto stop" off, a rotation angle of 180°, and trigger torque at 0.2 N·cm and the "0.5" position.

Root canal shaping began with VDW. ROTATE sequence (VDW GmbH, Munich, Germany) with instruments of sizes 15, 20, and 25, advanced slowly inside each canal until the motor's apical action stopped the motion (3). This was followed by refinement using ProTaper Ultimate F2 and F3 instruments (Dentsply Maillefer, Ballaigues, Switzerland) to conclude the shaping process.

To evaluate instrument fit, the flutes of the final rotary file were examined for debris, ensuring conformity to the canal's shape and dimensions. Debris-filled flutes indicate a proper match between the instrument and the canal's dimensions, indicating no need for a larger instrument to achieve further canal shaping.

Figure 1.
A 28-year-old female patient pre-operatory X-ray. The patient presented with throbbing pain to the lower right quadrant. Clinical examination found no abnormal extraoral findings. All lower arch teeth responded normally to diagnostic tests, except for the right mandibular second premolar, which exhibited sensitivity to cold stimuli. **A)** The periapical radiograph shows a deep distal caries and a slight enlargement of the periodontal ligament space without periapical radiolucency, confirming the diagnosis of "irreversible pulpitis". **B)** Intra-operatory X-ray. **C)** Post-operatory X-ray showing the precision of the technique.

Each canal was irrigated with 20 mL of 5.25% sodium hypochlorite (NaOCl; Ultradent Products, South Jordan, UT, USA) over five minutes using an irrigating needle (IrriFlex; PD Produits Dentaires, Switzerland) positioned approximately 1 mm from the root apex and activated with an ultrasonic activator (EndoActivator, Dentsply Sirona, York, PA, USA). Final irrigation was performed using 5ml of 17% EDTA (CanalPro; Coltene-Endo, Cuyahoga Falls, OH, USA) to remove the smear layer, followed by 5ml of 5.25% NaOCl (2).

The canals were dried with sterile paper points (VDW GmbH, Munich, Germany). Before obturation, an intra-operative X-ray was taken to confirm the precision of apical preparation and the adequacy of the apical seal (Figure 4).

Root canal obturation was achieved performing a single cone technique using ProTaper Ultimate gutta-percha cones conform fit (Dentsply Maillefer, Ballaigues, Switzerland) in combination with a hydraulic calcium silicate-based materials (BioRoot RCS, Septodont, Saint-Maur-des-Fossés, France), ensuring a hermetic seal.

Postoperative Results

Post-operative results were assessed through a combination of clinical evaluation, periapical radiographs, and patient-reported outcomes (e.g., post-operative comfort and functionality) at 1, 3, 6 months, and 1 year.

For Cases A and C (irreversible pulpitis and previously initiated therapy), the primary outcome measure was identified as the patient-reported outcome measure of 'tooth survival'(2). Additional critical outcomes included 'pain, tenderness, swelling, and need for medication (analgesics)', 'tooth function' (assessed through fracture and restoration longevity), 'need for further intervention', and 'adverse effects' (such as exacerbation, restoration integrity issues, and allergy). Clinician-reported outcome measures included 'evidence of emerging apical radiolucency' and 'presence of sinus tract' (16).

For Case B (Apical Periodontitis), the most critical outcome measure was identified as 'tooth survival'(2). Other critical outcomes included 'pain, tenderness, swelling, and need for medication (analgesics or antibiotics)', as well as radiographic outcomes, using loose and strict criteria, such as 'evidence of reduction in apical lesion size' (using loose criteria) and 'normal periodontal ligament space' (using strict criteria) (16). Precisely, the term loose criteria refers to a partial radiographic healing, defined as a reduction in the size of the apical radiolucency compared to baseline, while strict criteria require complete resolution of the radiolucency and restoration of a normal periodontal ligament space. These definitions are consistent with the recommendations of the European Society of Endodontology (ESE) (16). Additionally, other important outcomes were noted, including 'tooth function' (evaluated through fracture and restoration longevity), 'need for further intervention', 'adverse effects' (such as exacerbation, restoration integrity issues, or allergy), and the 'presence of a sinus tract'.

The ESE recommended observation pe-

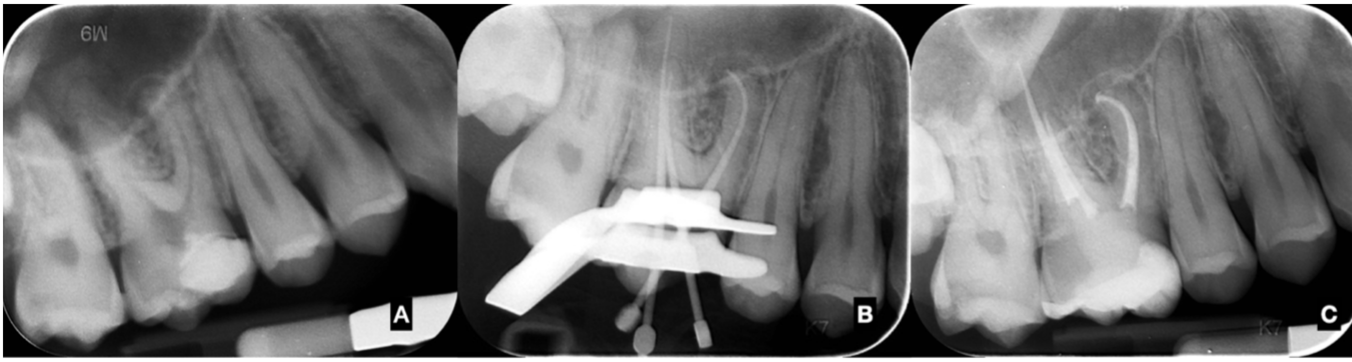

Figure 2.
A) 32 years old patient with symptomatic apical periodontitis with a history of intermittent pain, pain on percussion, and a negative response to the cold test, showed slight periapical radiolucency in the mesial root. **B)** Intra-operatory radiograph and **C)** post-operatory radiograph showing the positive radiographic outcome.

riods for these outcomes. For all outcomes except 'pain, tenderness, swelling, and need for medication (analgesics)', a minimum follow-up of 1 year and a maximum of 'as long as possible' was advised. For 'pain, tenderness, swelling, and need for medication (analgesics)', the observation period was set to a minimum of 7 days and a maximum of 3 months (16).
Overall, the chair time was 53,3 ± 6.2 minutes. Postoperative radiographs confirmed precise apical seals with no signs of over-instrumentation.
For all the cases, the primary patient-reported outcome measure of 'tooth survival' was fully met. Postoperative evaluations conducted at 1, 3, 6 months and 1 year revealed complete healing in all three cases (Case A, Case B, and Case C), as evidenced by the successful achievement of all defined outcomes. Additionally, all critical outcomes were satisfied, including the absence of sinus tract, pain, tenderness, swelling, or need for medication (analgesics), and presence of restored 'tooth function' (with no fractures or issues with restoration longevity) (Figure 9). For Case A and B clinician-reported outcomes confirmed the absence of 'evidence of emerging apical radiolucency'. For Case C radiographic assessments demonstrated complete resolution of apical lesions, meeting both 'evidence of reduction in apical lesion size' (loose criteria) and 'normal periodontal ligament space' (strict criteria) (17).
Overall, the findings align with the recommendations of ESE regarding the observation periods for these outcomes. The absence of clinical symptoms and radiographic evidence of pathology at the final follow-up underscores the efficacy of the treatments across all three cases.

Patient Perspective

All three patients reported a positive overall experience with the treatment protocol. They appreciated the streamlined nature of the procedure, particularly the reduced chair-time and minimal post-operative discomfort. Notably, none of the patients experienced post-operative pain at any point, and all reported immediate comfort following the procedure. The clarity of communication regarding each treatment step, combined with the use of advanced technology, contributed to a heightened sense of trust and confidence in the clinical process. Patients noted significant improvement in symptoms shortly after the procedures and expressed satisfaction with the functional and aesthetic outcomes. At follow-up visits, all patients emphasized their comfort during the interventions and reported a high level of satisfaction with both the treatment experience and the clinical results.

Discussion

The present study introduces a novel and simplified protocol for root canal shaping, highlighting the effective integration of the OAS2 apical function of the Morita Tri Auto ZX2+ motor, the ProTaper Ultimate system, and conform fit gutta-percha cones in order to achieve precise apical preparation and obturation. This strategy seeks to streamline procedures, reduce

Figure 3.
A 52-year-old male patient with a previously initiated therapy on the upper right third molar **A)** Pre-operatory periapical radiograph of the the tooth showing Cavit (3M ESPE, Seefeld, Germany) and a partial endodontic therapy, requiring further treatment. **B)** Intra-operatory periapical radiograph showing a complex anatomy with three canals. **C)** Postoperative periapical radiograph demonstrating a favorable immediate radiographic outcome.

treatment time, and minimize the risk of over-instrumentation. To the best of our knowledge, this represents the first report to integrate the use of OAS2 to offer an easily applicable workflow to implement in everyday practice, posing the bases for further research.

These results support the clinical viability of the proposed workflow and should be interpreted within the context of existing evidence. The patients reported no postoperative complications. A six-month follow-up showed complete resolution of symptoms, confirming the success of the treatment protocol.

By using controlled reversing movements to avoid over-instrumentation, the original OAS technique significantly facilitate root canal preparation. When it reaches the apical endpoint, the motor reverses 180° to 360° in the cutting direction before stopping, reducing apical binding and limiting risks of file overextension. Although efficient, this mechanism was depended on the cutting direction of the file, limiting its versatility. Additionally, the single reversal motion, although suitable for many cases, may not be able to handle more complex root canal anatomies, such as curved or narrow canals. In light of these limitations, the OAS2 system introduced a refined mechanism that employs bidirectional reciprocating movements to enhance control and safety. Before stopping, the motor performs two alternating rotations of +180° clockwise and -180° counterclockwise. This bidirectional reciprocation is independent of the file's cutting direction, making the system compatible with a broader range of file designs and clinical scenarios. The repeating motion of OAS2 reduces the possibility of instrument separation by more equally distributing mechanical stress along the file in addition to more successfully disengaging the file from apical binding. These features provides significant benefits. In addition to increasing flexibility in curved or calcified canals, the alternating action lowers the possibility of procedural mistakes like over-instrumentation or debris extrusion. Additionally, by eliminating the dependence on cutting direction, OAS2 facilitates integration with modern file systems, increasing versatility and efficiency in clinical practice. In summary, OAS2 refines the capabilities of OAS, moving from basic reversing movements to advanced reciprocating motions, thus improving safety, precision, and compatibility for modern endodontic treatments.

To the best of our knowledge, no studies have evaluated the efficacy of OAS2. However, a previous investigation (2) demonstrated that the combination of OTR motion and OAS achieved remarkable apical accuracy, with 75% of cases falling within the highly precise 0.0 to -0.5 mm range from the apical foramen. This level of accuracy surpassed other combinations, such as OTR with AAR, or the use of continuous rotation with AAR or OAS, which yielded success rates below 50%. This closer approximation to the apical foramen with OTR motion and OAS may be attributed to the algorithm controlling the instrument tip position which triggers the apical function and the torque control mechanism initiating reciprocating motion (3). Another ex-vivo study compared the precision of the electronic apex locator and automatic apical stop (AAS) function capabilities of Morita Tri Auto ZX+ and another cordless apex locator in determining WL. The results indicated consistent and accurate measurements with neither device exceeding nor falling short of the critical 1 mm margin crucial for successful endodontic treatments (10).

In contrast to AAS, which primarily halts movement based on WL, OAS2 not only stops the file but actively disengages it from apical binding through its reciprocating action. This lowers the chances of file separation and guarantees safer operation, especially in difficult situations involving curved or narrow canals. Moreover, OAS2 is not affected by the cutting direction of the file, therefore it is more adaptable and compatible with a wider range of file systems.

Furthermore, following the use of any NiTi systems, refining canal preparation with ProTaper Ultimate F2 and F3 instruments offers geometric advantages (5), such as a progressive taper design that improves canal shaping consistency and makes cleaning and debris removal easier. The instruments' cross-sectional design and cutting efficiency improve dentinal debris removal, enhance irrigation efficacy, and reduce the risk of canal transportation (18). The precise tip sizes and tapers of F2 and F3 instruments ensure a tight apical seal, minimizing apical leakage. In the end, using dedicated ProTaper Ultimate conform fit gutta-percha cones improves obturation quality even more and ensure a reliable seal that effectively prevents reinfection.

It is well known that the WL can vary across different stages of chemo-mechanical preparation (19). Traditionally, the WL was determined manually, leading to errors such as inaccurate length identification, lack of parallelism during measurements, and extended chair-time. In contrast, integrating EALs into endodontic motors allows continuous monitoring of file position throughout treatment, eliminating the need for recalibration (3).

It has been demonstrated that when the therapeutic procedures were shorter than 2 mm from or past the radiographic apex, the success rate for infected canals was approximately 20% lower than that when the procedures terminated at 0 to 2 mm (20). Furthermore, a large body of evidence demonstrated that it is clinically preferable to fall slightly short of the actual length rather than exceed it, as the latter is more likely to lead to unfavorable outcomes (2, 6, 8, 13, 21). The present protocol eliminates the chances of over-instrumentation. In accordance with previous studies, in this workflow all measurements were performed using the "0.5" display mark to determine working length, with manufacturers claiming that this displays mark indicate the position of the apical constriction, which in reality it is an arbitrary indicator of the apical position of the file (6, 22, 23). An important clinical observation across all three cases was the complete absence of postoperative pain, as reported by the patients during follow-up. This favorable outcome may be attributed not only to the precise apical control achieved through the OAS2-guided instrumentation, which minimizes apical extrusion and tissue trauma, but also to the use of a hydraulic calcium silicate-based sealer which have been shown to possess excellent biocompatibility, anti-inflammatory properties, and the ability to promote periapical healing. Their low cytotoxicity and excellent sealing ability may significantly reduce the incidence of immediate postoperative discomfort as demonstrated in a previous study (24). Therefore, the combination of a conservative, controlled preparation technique and the use of a hydraulic calcium silicate-based materials likely contributed to the patients' immediate postoperative comfort and absence of pain.

This simplified approach to root canal treatment seeks to drastically cut down on treatment time compared to traditional methods. These new sophisticated features automate critical steps in canal preparation, reducing the need for manual adjustments and recalibrations. This automation not only improve accuracy, but also saves chair-time.

The present protocol presents several limitations, particularly concerning the accuracy of electronic apex locators, which can be influenced by factors such as cervical flaring, tooth length, instrument size, anatomical variations, irrigating solutions, and canal contents. Furthermore, previous research has highlighted that integrated motors like the Tri Auto ZX2+ may be affected by variables such as the presence of gutta-percha (25), the use of 0.9% saline as an irrigating solution (26), and the choice of the apical mark (26, 27). Another limitation is that all cases were performed by a single expert operator, without accounting for different levels of operator experience. Further research is necessary to fully assess how different conditions, such as variations in shaping instruments, motor settings, operator expertise, and tooth anatomical variations, may affect the performance of this motor system. Moreover, future studies should rigorously examine the clinical effectiveness of this new shaping protocol across a range of clinical scenarios and analyze and comprehend its performance under controlled conditions.

Conclusions

This protocol has the potential to accelerate and streamline endodontic procedures, resulting in reduced chair time and enhanced procedural simplicity. Further research is needed to investigate its benefits across larger sample sizes and test different operator experience levels.

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