Resolution of endodontic issues linked to complex anatomy

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Summary

Anatomical abnormalities of the root canal system are frequently seen in specialist endodontic practice, and represent a challenge to be faced with skill and thoroughness, beginning with an accurate diagnostic phase and devising the most appropriate treatment plan. Fortunately, much progress has been made in endodontic research thanks to technological advances and the evolution of higher performance instruments, which now consent even very complex cases to be resolved with relative ease. Below are described the salient features of recent progress in endodontics, along with a description of several clinical cases in which the operator has encountered numerous difficulties due to peculiar tooth morphology, overcome successfully thanks to the application of modern tools and consolidated clinical experience in the field.

Key words: complex endodontic therapy, endodontic anatomy, endodontic diagnosis, nickel-titanium instrumentation, tooth morphology.

Introduction

Since the 1990s, great strides have been made in endodontics, consenting the achievement of ever more predictable and long-lasting outcomes. The introduction of new instruments and technological aids have led to the development of a completely different approach to root canal treatment, and have advanced techniques that favour the resolution of even complex cases are now becoming routine in the specialist practice (1). As regards the tools used for root canal therapy, the use of manual files in conjunction with mechanical drills (e.g., Gates-Glidden and Largo drills) to remove interference in the pulp chamber and the coronal portion of the canal has all but been superseded. Nowadays, mechanical files mounted on handpieces equipped with speed reducers and purpose-designed engines are prevalent in endodontic applications. These devices also benefit from the favourable properties of nickel-titanium alloy (used to make them) and increased taper. Moreover, the latest generation of nickel-titanium (NiTi) instruments are very flexible and are better able to adapt to even the most accentuated curvatures. Thanks to their more enhanced cutting tips, they also consent more flared, more tapered and more predictable preparations to be made in considerably shorter time-frames than those required to perform similar procedures using manual stainless steel files. First and foremost among the technological aids at the endodontist's disposal nowadays is without doubt the electronic apex locator, which has become much more reliable and performs far better than in the past. Indeed, it allows such precise location of the apex and determination of the working length (2) that many specialist endodontists now refrain from performing x-rays during surgery altogether. Nevertheless, in cases of anomalous endodontic anatomy, there is a high risk of morphological features complicating the correct measurement of the working length, so particular care needs to be taken in these cases (3). Thankfully, however, with the aid of magnification devices such as Galilean or prism loupes and especially the operating microscope, endodontists are able to observe the operating field up close, and are therefore better equipped to deal with such troublesome anatomy (4). Thus, the specialist endodontist now has a range of simplified and more rapid techniques at his disposal. That being said, it is not the instruments that must perform the therapy, so the specialist endodontist should also be equipped with a complementary degree of experience, skill and know-how, particularly in the use of this array of instruments (manual and mechanical) and devices (radiological and diagnostic). With this combination, even the most complex clinical situations can be resolved successfully (5).

The endodontist is likely to have a better idea of the root canal system anatomy in question before beginning treatment, although he must be ready to deal with surprises, as it turns out to be far more complicated than initially foreseen in a high percentage of cases (Fig. 1). The operating microscope is invalu-

Figure 1. Post-operative x-ray with correct endodontic filling.

able in such cases, and as well as applications in endodontic surgery that have by now become routine, is ever more commonly used in orthograde endodontics in specialist practice, especially in retreatment and difficult cases (8). Indeed, magnification of the operating field is fundamental for observing complex features of the endodontic anatomy and identifying any misrecognized, accessory or lateral canal, foramina and particular anatomical conformations (e.g., c-shapes, isthmuses, anastomoses). In retreatment, this device is extremely useful in aiding the removal of posts or fragments of files broken off inside the canal (9). Furthermore, it may be the only means able to confirm a diagnosis of probable fracture, consenting an otherwise invisible crack to be discerned. Radiological examination is also very important, and is generally performed using digital support nowadays: both orthopantomography and periapical-endoral x-ray data can be processed using purpose-designed software and image optimization that can reveal pathologies and varying degrees of anatomical complexity that are undetectable by clinical examination alone. Furthermore, the recent introduction of cone-beam computed tomography (CBCT) now consents observation in three-dimensional space with a very low biological cost (they emit a considerably reduced quantity of radiation with respect to conventional CT). CBCT also has a sub-millimetricresolution and is therefore useful for examining fine detail with extreme precision (10). Its major application is in implant surgery, but it is also very useful in orthograde, and especially retrograde, endodontics, helping to identify and locate apex lesions, anatomical variants and relationships with adjacent anatomical structures (maxillary sinus, inferior alveolar nerve). Moreover, it consents visualization of external and internal resorption, as well as root canal perforations and fractures, accessory canals and lateral apices (11). In fact, a recent study by Patel and Horner (12) highlighted the fact that CBCT can be used to diagnose almost 100% of apex lesions, as compared to 28% using conventional endoral x-ray. Zhang et al. (13) also used CBCT to highlight the frequency of triradicular lower first molars (43% even featured four canals) and the

C-shaped configuration of the lower second molars in a Chinese population.

The anatomy of the secondary components (secondary canals, apical deltas, anastomoses, isthmis, curves) of the root canal presents extreme variability, even though its primary components (main canal, pulp chamber, foramina and apices) generally conform to standardized models based on the probability of a certain configuration. The teeth, which generally present the greatest anatomical complexity, are without doubt the upper molars, especially the first, in which four canals distributed among three roots are very common indeed (62%). The mesiobuccal root of these teeth usually presents two canals in one of various configurations: 37% being Weine type II (2 coronal orifices and 1 apical foramen) and 25% Weine type III (2 distinct canals). Other teeth that are rather complex to treat due to their anatomy are the lower incisors, as these present 2 buccal-orally distributed canals in 42% of cases. The lower premolars are also prone to anomaly, and in 26% of cases feature a configuration with two canals (Weine type II or III) (14). On the whole, the anatomy of the other teeth is far less variable, although some exceptions are seen (see reported cases). The curvature of the root can also be problematic, in that abnormalities are common and not easily detected by radiographical means. The root curvatures most worth of note are the double distal-palatine curve of the upper lateral incisors and the curved buccal side of the palatine root of the upper molars; these can easily deceive the endodontist in that their apices are difficult to see properly on x-ray, and it is therefore easy to make an inappropriate choice of tools. This in turn can lead to perforation or false paths, which are difficult to redress after the fact. One anomalous morphological characteristic that can be observed with some frequency in the lower molars (although cases have been reported in the upper molars and lower first premolars) is a C-shaped pulp chamber. C-shaped mandibular molars are so called due to the cross-sectional shape of their root and canals; instead of having several different orifices, the pulp chamber of this type of tooth displays a single cestoid orifice with an arc of 180° (or more), which begins at the angle with the mesiolingual line and extends buccally or lingually in a circular fashion, ending in the vicinity of the distal wall. Below the orifice of the C-shaped molar, a wide variety of anatomical variations in the structure of the canal system are possible. These variants can be classified into two groups: (a) those featuring a single cestoid C-shaped canal extending from the orifice to the apex; and (b) those featuring three distinct canals below the C-shaped orifice. The latter type is far more common than the former, which represent the exception rather than the rule (15).The prevalence of C-shaped molars is strongly influenced by racial factors. In fact, this anatomical variant is far more common in Asian populations with respect to Caucasians (16). Developmental dental defects can also cause procedural difficulties in endodontic treatment. These anomalies can be classified as follows:

- Fusion: fusion of two adjoining teeth due to close contact between tooth buds; this can involve the entire teeth or only the crowns;
- Gemination (twinning): incomplete division of the tooth bud resulting in an otherwise normal tooth joined to its supernumerary offshoot;
- Concrescence: fusion of the cementum of two adjoining teeth, generally due to trauma;
- *Dens in dente* (*dens invaginatus*): the development of part of a tooth inside another; the defect is termed coronal, radicular or corono-radicular, depending on the portion of the tooth it occupies.

Weinstein et al. reported a clinical case of geminated upper second molar that, despite the anatomy-related difficulty, they managed to treat with the aid of an operating microscope and ultrasonic tips. Likewise Zeylabi et al. (17) successfully treated a lower third molar fused with a supernumerary disto-molar. Aguiar et al., on the other hand, described complex endodontic treatment of a lower premolar with two roots and three canals. Other authors (18) have presented a case of *dens in dente* of an upper canine, treated satisfactorily despite the complexity of the internal morphology of the canal system.

Clinical series

In complex clinical situations it is necessary to perform careful evaluation of the case beforehand and establish an appropriate treatment plan, otherwise there is a risk of underestimating the problem. This can lead to failure, not only of the root canal therapy itself, but also of the subsequent direct or indirect restoration. Indeed, this was the case in a patient who presented caries pathology with pulpal inflammation at the 3.3, which needed to be used as anchorage for a mobile prosthesis and was accordingly restored by means of a glass-fibre intracanal post and a ceramic-fused-to-gold crown. Upon completion of treatment, which lasted roughly six months, the patient continued to complain of discomfort at the canine while chewing. This was initially attributed to a problem of occlusion, but digital magnification of the periapical-endoral x-ray showed that the tooth featured a further oral root that had previously escaped notice and had therefore not been treated (Fig. 2). Once the problem had been identified, the case was simple to resolve, and the symptoms disappeared upon treatment of the painful root (Fig. 3). A similar clinical case was that of an upper premolar that presented three roots, two buccal and one palatal, a tooth that had previously been treated and restored with a single crown (Fig. 4). Also in this case, close examination of the x-rays brought to light the unexpected anatomical variant and retreatment resolved the pain (Fig. 5). Both cases, despite their diagnostic complexity, were not particularly difficult to treat. However certain cases of shape anomaly are more troublesome, especially during the operative phase (17). This was the case in a patient who reported algic symptoms in the left lower sector. Scrutiny of the or-

Figure 2. X-ray of a left mandibular canine with two roots and two canals (one untreated).

Figure 3. Post-operative x-ray.

Figure 4. X-ray of a right upper premolar that presented three roots, two buccal and one palatal.

thopantomograph (OPT) (Fig. 6) revealed a deep obturation troubled by caries relapse on the mesial surface of the left lower second molar, which was fused to the adjacent third molar (Fig. 7). Root canal treatment was hampered by the peculiar anatomy, especially in the pulp chamber shaping phase and the identification of the canal orifices. In particular, four canals were present: larger mesial and distal (Fig. 8) and two smaller intermediate (Fig. 9); the mesial canal was housed in the mesial root, while the other three were all found in the distal (Fig. 10). Accentuated curves can also cause some difficulty during root canal therapy (Fig. 11). In the past these would have been treated using pre-curved stainless steel files, an operation that took considerable time, and one that would have led to canal straightening. Today, however, thanks to modern NiTi files and the use of a mixed technique (stainless steel – NiTi) more flared preparations can be accomplished and the original curvature maintained without undue time being necessary. This was the case in a patient presenting to our attention with considerable pain in the fourth quadrant. Clinical examination and OPT revealed a, by then, incongruent bridge spanning four tooth positions (from 4.5 to 4.8), whose posterior supporting tooth had become affected by secondary caries and pulpitis (Fig.

Figure 5. Post-operative x-ray.

Figure 6. Orthopantomograph that revealed a deep obturation with secondary caries on the mesial surface of the left lower second molar.

12). The patient did not wish to undergo osseointegrated implant surgery and so the only option, without resorting to a mobile prosthesis, was treatment and restoration of the 4.8. The anatomy of the third molar is known for its complexity and abnormality, and this

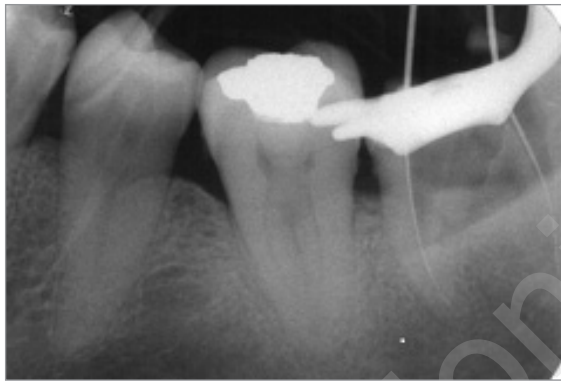Figure 7. Left lower second molar fused to the adjacent third molar.

Figure 8. Intra-operative x-rays for working length.

Figure 9. Intra-operative x-rays for working length.

Figure10. Post-operative x-ray.

Figure11. Post-operative x-ray with correct endodontic filling.

Figure 12. Orthopantomograph that revealed incongruent bridge spanning four tooth positions (from 4.5 to 4.8), whose posterior supporting tooth had become affected by secondary caries.

case was no exception; it was mesiodistally elongated, buccolingually narrow and featured two roots with two canals of accentuated distal curvature. In spite of the considerable challenges presented by the case, it was resolved successfully by a mixed technique us-
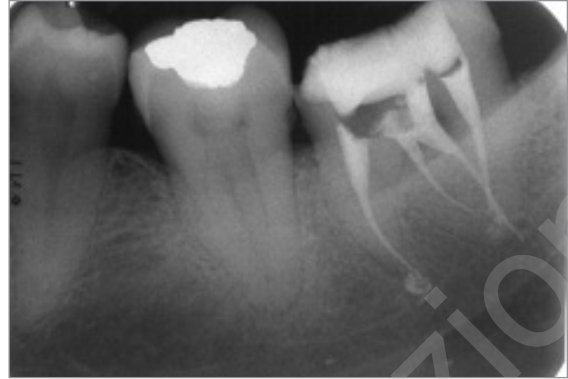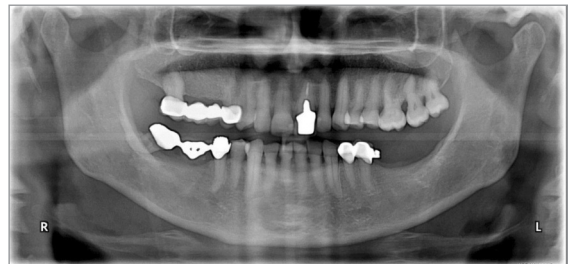
ing manual stainless steel and rotary NiTi files; the tooth was then restored via the insertion of two glass-fibre posts and prepared as a posterior support for the fixed prosthesis of 5 teeth, thereby rehabilitating the patient's fourth quadrant (Fig. 13). Another complex case to treat is the so-called "MB2," or fourth canal (two in the mesiobuccal root), of the upper molars. It is mandatory to look out for this defect as it is

present in a high percentage of patients. In such cases, (Fig. 14) the canal is often very narrow and curved, and needs to sought in the mesiobuccal root (Fig. 15) displaced palatally and slightly mesial to the main mesiobuccal canal (Fig. 16).
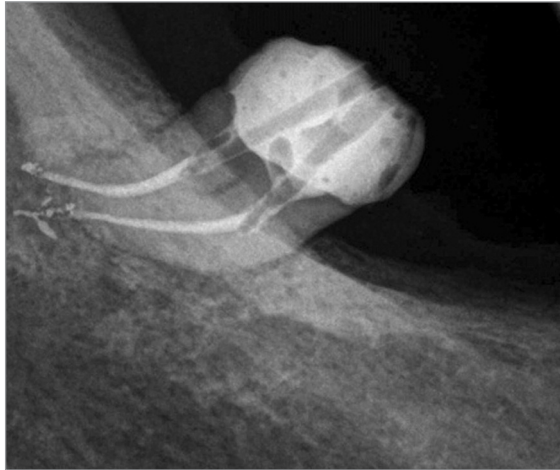

Figure 13. Post-operative x-ray with correct endodontic filling and build up with two glass-fibre posts.

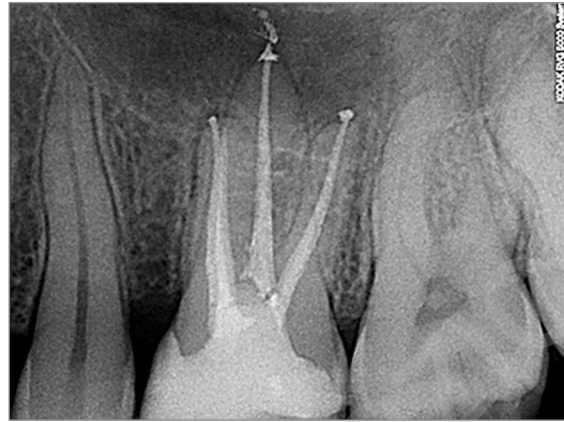Figure 14. Pre-operative x-ray of left first maxillary molar.

Figure 15. Post-operative x-rays with correct endodontic filling and evidence of the "MB2" canal.

Figure 16. Post-operative x-rays with correct endodontic filling and evidence of the "MB2" canal.

Discussion

Diagnosis is one of the fundamental steps in medicine and dentistry in general, and for endodontics in particular. Indeed, an appropriate treatment plan cannot be defined without accurate diagnosis and a thorough preliminary study of the clinical case; only in this way will it be possible to deal with unexpected occurrences in the best possible fashion (6). The endodontic anatomy is particularly challenging and for the clinician, so an optimal diagnostic approach, suitable access techniques and highly professional skill are indispensable for the successful location,

preparation, disinfection and sealing of the root canal system (7). Nowadays, however, when planning treatment, the endodontist can rely on far greater safety and precision in diagnostic tools with respect to the past.

Conclusions

Endodontics is an extremely important branch of dentistry whose aim is the recovery of severely compromised teeth. This can be accomplished with varying degrees of difficulty, depending on the complexity of the clinical case in question. As we have seen, particularly complex cases need to be managed with particular care in both the diagnostic and intervention phases, both of which can be greatly aided by the advanced technologies, instruments and innovative materials at our disposal. These not only serve to simplify techniques, but also confer results with greater out-

come predictability and long-term success rates with respect to the past, even in extremely difficult cases (19). It is therefore vital that an endodontist is highly skilled, a specialist able to deal with even the most complex clinical situations, in both orthograde treatment and retrograde surgery. Furthermore, the modern-day endodontist needs to be proficient in post-endodontic restoration, managing adhesive reconstruction techniques and endocanal posts, in order to obtain a tight seal at both the crown and the apex, both necessary to ensure the success of treatment. In line with international trends, the philosophy of our school is that the endodontist should be able to complete and resolve the case of a severely compromised tooth from beginning to end, including, as a last resort (when it cannot be saved) its extraction and replacement with an osseointegrated implant (20).

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