Comprehensive Management of Impacted Teeth in Cystic Lesions of the Jaws

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Cystic lesions in the jaws are frequently associated with impacted teeth, and include dentigerous cysts, odontogenic keratocysts, unicystic ameloblastoma and adenoid odontogenic tumours. The most common treatment modality is enucleation of cysts with removal of the impacted tooth. Marsupialisation is a more conservative treatment modality than enucleation and is considered the first-line treatment, especially in the initial management of benign cystic lesions during the mixed dentition period. Depending on the size of the lesion, the position of the impacted tooth and the available space, the majority of teeth can erupt spontaneously after marsupialisation. A multidisciplinary approach has been used in recent years for management of these lesions. Orthodontic traction is sometimes performed on the impacted tooth to guide tooth eruption postoperatively. When an impacted tooth or teeth within cystic lesions are preserved and functional occlusion is obtained, the patient's quality of life can improve significantly. Prospective clinical trials with a larger patient cohort are necessary to determine the clinical benefit of the conservative approach with marsupialisation or surgical-orthodontic treatment of impacted teeth in cystic lesions since only studies of small groups of patients or case reports have been published to date.

Keywords: *cystic lesions, enucleation, impacted tooth, marsupialisation, orthodontic traction*
Chin J Dent Res 2025;28(1):19–30; doi: 10.3290/j.cjdr.b6097603

A cystic lesion is a pathological cavity that contains fluid or a semisolid material and is lined by epithelium.[1] Most cysts in the jaw are lined by epithelium that is derived from odontogenic epithelium and are referred to as odontogenic cysts.[2] Odontogenic keratocysts (OKCs) and unicystic ameloblastomas (UAs) can share a similar clinical and radiographic presentation to dentigerous cysts (DCs).[3] Cystic lesions in the jaws are usually asymptomatic, and may be detected incidentally via routine radiographic examinations or when they are large enough to cause facial asymmetry.[4,5] The expansion of cystic lesions may impinge on surrounding structures, such as the inferior alveolar nerve or roots of adjacent teeth, resulting in paraesthesia, tooth displacement or root resorption. They may displace or obliterate the maxillary sinus, nasal cavity and orbital cavity, which leads to diplopia.[6,7]

Cystic lesions in the jaws have been commonly found to be associated with unerupted teeth. A vast majority of DCs are associated with impacted mandibular third molars, followed by permanent maxillary canines and maxillary third molars[8]; however, in a literature review about DCs in children, Tuwirqi et al[5] found that the substantial majority of DCs involve the mandibular second premolars and second molars followed by the maxillary permanent canines, but rarely the mandibular incisors. Mandibular OKCs and UAs are often associated with impacted third molars, with some reports indicating that up to 80% of these lesions occur around an unerupted mandibular third molar.[9,10] It is commonly found that adenoid odontogenic tumours (AOTs) and calcifying odontogenic cysts (COCs) are associated with impacted teeth.[11]

The standard treatment for cystic lesions involves enucleation and extraction of the affected teeth. During

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removal of the lesion, extraction of the unerupted permanent third molar, inverted or severely dislocated impacted tooth or supernumerary tooth is usually carried out.[6,12,13] When preservation of the impacted teeth is planned, marsupialisation is a rather conservative treatment option, and has the advantage of promoting spontaneous eruption of the affected tooth within the cyst.[4,14] In preadolescents, a permanent tooth in a DC often erupts successfully after having undergone marsupialisation and resolution of the cyst.[14,15] Combined orthodontic-surgical techniques may help promote cyst-related tooth eruption, but treatment plans are difficult to carry out for huge cystic lesions with deeply impacted teeth. In these circumstances, enucleation and simultaneous removal of the impacted teeth may cause nerve injury or pathological mandibular fracture during surgery. DCs with deeply impacted mandibular third molars can be treated by means of marsupialisation with orthodontic traction.[16] This orthodontic-surgical procedure may reduce the risk of nerve damage and pathological fracture of the mandible. In these cases, coronectomy is an elective procedure that poses decreased risk of nerve injury or mandibular fracture.[17]

Marsupialisation or surgical-orthodontic treatment for cystic lesions has been widely recommended in order to preserve the impacted teeth and create favourable conditions for the further development and function in the oral-maxillary structures. Preservation of cyst-associated teeth requires a reliable and intuitive protocol, thus the present authors systemically reviewed the types of cystic lesions of the jaws and various methods of managing these lesions based on recent publications in the literature.

Types of cystic lesions of the jaws associated with impacted teeth

DCs are developmental cysts associated with impacted teeth, but other odontogenic cystic lesions, including OKCs, orthokeratinised odontogenic cysts (OOCs) and UAs, sometimes share a similar presentation to DCs.[3] Clinical, radiographic and histological evidence is often required to make appropriate diagnoses and manage these lesions.

DCs

DCs are the second most commonly observed type of odontogenic cyst after radicular cysts, and are the most common developmental cyst found in the jaws.[8,18] They occur most frequently in the posterior mandible and maxilla, and are most often associated with an impacted third molar.[19-21] The second most prevalent location for them is the maxillary canines, but some cysts occur around premolars or very rarely, around incisors and supernumerary teeth.[8,22] Benn and Altini[23] were the first to propose the classification of DCs based on their aetiology by dividing them into two separate groups: DCs of developmental and inflammatory origin. Inflammatory DCs are most commonly located in the premolar region, with the non-vital primary tooth still present in the dental arch.

DCs are more commonly found in patients in their second and third decades of life than in older age groups.[19,20] It was reported that the mean age of children with DCs was between 11.05 and 11.60 years.[1,24] The late mixed dentition period corresponds to the time at which the crowns of permanent teeth have developed completely and have started to erupt. Thus, DCs in paediatric populations may occur more frequently in the late mixed dentition stage because during this time, there is a higher probability of impaction of the maxillary canines, as well as of periapical inflammation spreading from a non-vital primary tooth to involve the follicle of the unerupted permanent tooth.[24]

OKCs and OOCs

OKCs represent 4% to 11% of odontogenic cysts.[25,26] They frequently occur in patients aged between 10 and 40 years, and approximately 70% are located in the mandible.[26,27] OKCs have less of a tendency to expand buccolingually. Radiologically, OKCs present unilocular or multilocular radiolucency. Multiple OKCs are observed in association with nevoid basal cell carcinoma syndrome (NBCCS). An unerupted tooth is associated with the lesion in 25% to 40% of cases.[28] Importantly, OKCs exhibit a high recurrence rate, varying from 20% to 80%.[28,29] PTCH1 inactivating mutations were demonstrated in 93% of sporadic OKCs.[30]

The term OOC was first coined by Wright[31] in 1981 as a variant of OKC. Subsequent studies have demonstrated that OOCs do not share the same clinical behaviour, histological characteristics, PTCH1 gene mutation or association with NBCCS as seen in OKC.[32,33] There is a male predominance and the mean age of presentation is in the third to fourth decade of life.[34] The posterior mandible is the most common location for OOCs and up to two-thirds of reported cases are associated with an unerupted tooth.[35] Up to 50% of OOCs are asymptomatic and > 90% of cases present as a well-demarcated unilocular lesion.[33,34]

UAs

Ameloblastomas account for around 13% to 50% of all odontogenic tumours.[36] Of these, 5% to 22% of all ameloblastomas are of the unicystic type.[37] Conventional ameloblastomas and UAs may be associated with impacted teeth, particularly mandibular third molars; however, the majority of UAs have this clinical presentation.[38,39] UA presents in a younger age group, with 50% of cases reported in patients in the second decade of life in contrast to conventional ameloblastomas, which have a peak incidence in the fourth and fifth decades.[38,39]

AOTs

AOTs are a relatively rare benign lesion and account for < 5% of odontogenic tumours[37] and occur twice as frequently in female patients as in male patients. Canines are the most common unerupted teeth associated with AOTs. Lesions are unilocular in 91% of cases.[40] Generally, the disease occurs in the second decade of life.[40,41] Clinically, an AOT resembles a DC or an ameloblastoma. It is completely radiolucent and mimics a DC in terms of growth pattern and appearance; however, it often appears to envelop both the crown and roots of a tooth, and is seen as a corticated radiolucency with small radiopacities.

COCs

COC mostly affect the anterior region of the jaw and are most common during the second and third decades of life.[37,42] Radiographically, they appear as a well-circumscribed unilocular radiolucency containing flecks of indistinct radiopacities. The lesion encompassing the crown is attached to the cementoenamel junction.[11] In around one-third of cases, an impacted tooth is associated with the lesion.

Imaging evaluation and histology of cystic lesions

Imaging examinations

Imaging modalities used to evaluate cystic lesions of the jaws include intraoral radiography, panoramic tomography, CBCT, computed tomography (CT), MRI and ultrasound. Radiographs are a routine part of the diagnostic process and treatment planning. The classic radiological appearance of an odontogenic cyst in the jaws is a well-defined, round or oval area of radiolucency, circumscribed by a sharp radiopaque margin.[6,43]

Panoramic radiography and periapical films are the backbone of diagnostic imaging; however, plain radiography has several limitations, such as the superimposition of anatomical structures, and the inability to observe small changes in bone density. CT, especially CBCT, is a commonly used technique for evaluating the topography of cystic lesions of the jaws.[44-46] The integrity/discontinuity of the bony margins, dimensions, exact anatomical site of lesions, internal calcifications, proximity to vital structures and displacement and root resorption of teeth are well documented on radiographs. CBCT images are not distorted or enlarged, and have a margin of error of < 0.1 mm. In contrast, one multislice CT scan has a margin of error of 1.0 to 1.5 mm.[47] CBCT has a usual exposure dose that is 40 to 60 times lower than that of multislice CT.[48] The main advantages of CBCT over conventional CT are its very high spatial resolution, which introduces a 3D image in one rotation only with a lower dose and simpler technique.[45,49] Application of the technique can enhance the quality of the diagnosis and preoperative assessment of cystic lesions in the jaw and determine the optimal surgical treatment plan.[44,50,51]

DCs appear as a well-defined unilocular radiolucency associated with the crown of an unerupted tooth.[8,21,22] Often, the radiolucent area surrounds the crown, but sometimes it lies mainly or entirely to one side. The central type has been found to be the most common (60.6%), followed by the lateral type (29.2%) and the circumferential type (10.2%).[21] Unilocular lesions with the crown of an impacted third molar in the mandible may be DCs, OKCs or UAs, and it is impossible to distinguish these lesions through clinical or radiographic examinations.

A unilocular radiolucency with opacities and tooth displacement in the anterior region of the jaws is the radiological feature most characteristic of the majority of AOTs.[40] The follicular (pericoronal) type is associated with the crown of the impacted tooth. AOTs can be radiographically indistinguishable from DCs, but in around two-thirds of cases, small foci of radiopacity can be detected.[37,50] COCs are rare, accounting for < 1% of all odontogenic cysts. Radiographs of COCs reveal a well-defined radiolucent lesion, which is usually unilocular. Around half of all cases have amounts of calcified tissue.[37] A complex odontoma in its intermediate stage may mimic an AOT.

Histopathological examination

Clinical and radiographic examination alone cannot differentiate between the abovementioned cystic lesions

associated with an unerupted tooth, so a histopathological examination should be performed for all cystic lesions. A specimen of the cyst membrane is routinely sent for histological examination and diagnosis. The intraoperative frozen specimen can also detect an occult pathological condition.

Recognising the key histological features of the various odontogenic cystic lesions associated with the crown of an impacted tooth will aid in arriving at the correct diagnosis and ensuring appropriate clinical management.[3]

DCs

DCs are lined with nonkeratinising epithelium of uniform thickness of two to four layers of cuboidal/squamous cells, overlying fibrous or fibromyxoid stroma.[8,20,37] Small islands or cords of inactive-appearing odontogenic epithelial rests are usually present within the connective tissue. Scattered mucous cells, cilia, hyaline bodies and calcifications can be encountered in the cyst lining. If secondarily inflamed, the epithelium can become hyperplastic.

It may be more likely to encounter inflammatory DCs in paediatric populations.[23,24] Inflammatory DCs in paediatric patients may occur due to periapical inflammation of a primary tooth that spreads to involve the underlying follicle of the unerupted permanent tooth.[24]

OKCs and OOCs

The OKC shows corrugated parakeratinised epithelium without a granular cell layer, with a basal layer containing prominent palisaded and hyperchromatic nuclei.[8,37] Other histological findings in OKCs include budding of the basal layer. The dense fibrous connective tissue wall usually lacks inflammation unless it is secondarily inflamed. The satellite or daughter cysts of OKCs are more commonly seen in syndromic OKCs. Most OKCs are sporadic, but up to 5% of cases are associated with NBCCS. PTCH1 gene inactivation has been identified in around 90% of OKCs.[30]

OOCs are characterised by a thin, uniform epithelium of five to nine cell layers, lacking rete ridges. Thick, lamellated orthokeratin is present on the surface and a prominent granular cell layer is seen. The basal cells lack palisading and hyperchromatic nuclei.[3,37] The absence of PTCH1 mutations is confirmed by sequencing epithelial lining samples from 14 OOCs.[52]

UAs

Three histological growth patterns of UAs are recognised: luminal, intraluminal and mural.[38] The epithelium has the characteristic peripheral palisading and nuclear polarisation (reverse polarity) seen in ameloblastomas. Overlying the basal cells may be the vacuolated cells and loosely arranged epithelium, reminiscent of the stellate reticulum. The purely luminal variant is mostly associated with an impacted tooth, and is considered less aggressive.[37,38]

AOTs

AOT are benign epithelial tumours that have a duct-like structure.[37,53] They produce a variety of architectural patterns, most notably multiple, variably sized nodules of nondescript to spindled epithelial cells with minimal stroma. Within these nodules are variably sized rosette-like or duct-like spaces. These spaces are lined by a columnar or cuboidal epithelium, with the nuclei tending to be displaced away from the lumen.[37] Small foci of calcification are frequently seen within the tumour.

COCs

Histopathology in COCs is unicystic and is lined by epithelium of variable thickness with a wide range of histological characteristics. The key diagnostic feature is the presence of a well-defined basal layer of palisading columnar cells and a thick overlying layer resembling the stellate reticulum of the enamel organ, with focal accumulations of ghost cells, which may calcify.[37,42] A variable amount of dentinoid is sometimes laid down adjacent to the epithelial lining.

Marsupialisation or decompression of cystic lesions

Marsupialisation procedures

The standard treatment for cystic lesions is enucleation of the cyst with extraction of the teeth associated with it, particularly the third molar or supernumerary or malformed teeth.[54] In large lesions that pose a real risk of damaging important anatomical structures during enucleation, marsupialisation or decompression, coronectomy in conjunction with cystectomy may be considered. The first treatment option for DCs in children and preadolescents is marsupialisation or decompression as minimally invasive surgical procedures.[55,56] This

enables progressive reduction of the cystic lesion with minimal risk of injury to the adjacent structures, and promotes spontaneous eruption of the teeth involved.[1,57]

Marsupialisation and decompression are very similar surgical procedures aimed at decreasing the cystic size by reducing the pressure of the cystic fluid and inducing bony apposition to the bony surface in the void created by the shrinking cystic walls.[58-60] However, technically they have different meanings. Marsupialisation of cysts in the jaws with retention of part of the lining[6] creates a larger communication or pouch connecting the oral and cystic cavities after unroofing the outer wall of the cyst and suturing the cyst wall to the oral mucosa.[61,62] An obturator (cyst plug or acrylic stent) is fabricated and placed into the cavity to maintain patency after surgery.[63-65] Decompression, proposed by Thoma,[66] creates a smaller opening or connection between the cyst and the oral environment, which is maintained via a small-diameter polyethylene or rubber drainage tube until an epithelial slit forms.[67-69] Excised tissue (biopsy sample) from the epithelial lining is sent for histological examination during marsupialisation.

When preservation of the impacted teeth is planned, marsupialisation is a rather conservative treatment option,[4] and has the advantage of promoting spontaneous eruption of the involved teeth within the cyst.[14] Two studies found that between 71.4% and 72.4% of the individuals who participated presented with natural eruption of teeth enclosed in the cyst after marsupialisation was carried out.[14,15] Nahajowski et al[70] determined that almost 62% of premolars associated with DCs erupted spontaneously after marsupialisation of the cyst. The key factors involved in the eruption of the tooth in the arch are the status of root development and the angle and depth of the tooth in the jaw. The impacted teeth, together with incomplete root development, show potential for eruption if the angle was less than 25 degrees and the space between adjacent teeth was greater than the size of the teeth.[71] It is very well established that the mean amount of time it takes teeth to erupt without carrying out orthodontic traction is approximately 3 months.[14,15]

The impacted teeth without complete root formation or with an open apex have considerable potential to erupt after marsupialisation.[72] If the dental roots have been matured, the teeth might not erupt to the normal position after marsupialisation.[15,57,73] Patients aged over 10 years old would not be expected to experience spontaneous eruption of an impacted tooth, indicating the need for orthodontic treatment to guide occlusion or surgical removal of the entire cyst with impacted teeth.[71]

When large cystic lesions of the mandible are associated with deeply impacted teeth, enucleation and simultaneous removal of the impacted tooth may cause nerve injury or pathological mandibular fracture during surgery. Sun et al[74] found that after marsupialisation, all the cystic lesions shrunk and all impacted teeth with or without mature roots moved towards the bony windows, and the distance of tooth movement ranged from 8.3 to 12.1 mm, which facilitated tooth extraction during stage-two surgery (enucleation). After the second surgery, there were no occurrences of numbness in the ipsilateral lower lip or mandibular fracture, or indeed any other complications.[74] When the third molar is deeply impacted within the cyst cavity, a combined orthodontic-surgical procedure may further facilitate tooth extraction and reduce the risk of damage to the inferior alveolar nerve and the possibility of pathological fractures.[16,75]

Cyst plug or obturator

A cyst plug or obturator must be used to maintain patency of fenestration when marsupialisation of a cystic lesion in the jaw is performed. The cyst plug is usually inserted between 10 days and 2 weeks after marsupialisation. These obturators are designed and inserted, taking into consideration the missing tooth, the anteroposterior position of the lesion and the direction of marsupialisation. The obturator design is determined by the prosthodontist. Three types of obturator prosthesis have been designed,[76-79] namely the clasp type, consisting of a retainer and obturator; the denture type, consisting of a retainer, artificial tooth, denture base and obturator; and the plug type, consisting only of an obturator.[78] Significant differences among the three obturator groups were found for age, number of remaining teeth, location, direction of marsupialisation (labial, buccal or occlusal surface) and pattern of missing teeth (free-end, bounded or none missing). Clasp- and denture-type obturators, which use retainers, require invasive rest seat preparation on the abutment teeth. When the loss of an anterior tooth or premolar occurs after marsupialisation, the device used is an obturator in acrylic resin incorporated in a removable partial denture,[79] and a denture-like obturator can be provided for space maintenance and masticatory function.[56,79] Because obturator design has a minimal effect on the ability of the appliance to maintain the surgical opening, it is preferable to use the least invasive design (plug-type obturator).

A one-piece cast appliance is fabricated to maintain patency of the cyst fenestration when marsupialisation of a cyst in the jaw is performed.[80] The appliance con-

sists of a clasp, a connector and an insert, formed as a one-piece casting of chromium alloy and attached to a tooth or teeth adjacent to the surgical site. A one-piece cast appliance has several advantages: positive retention, stability and comfort; minimum irritation of the wound margins; positive maintenance of the orifice diameter; no irritation of the periodontal attachment of the ligated tooth; ease of removal for cleaning and irrigation; and radiopacity of the appliance.[80] However, postoperative modification of the appliance is not easy to perform compared with acrylic resin.

The clasp and base of the traditional cyst plug play the main role for retention[78,79]; however, because of the anatomical shape and arrangement of the teeth in teenagers in the mixed dentition stage, the retention force of the cyst plug is often insufficient, which may lead to accidental swallowing. Therefore, a vacuum-formed cyst plug is designed,[81] whose retainer, the vacuum-formed part, covers the entire dentition and plays an important role in retention. The plug body is responsible for maintaining drainage. This vacuum-formed cyst plug may replace the classic one, and provides a more comfortable experience for children in the mixed dentition stage.

After insertion, all patients are advised of the importance of wearing the prosthesis continuously and are recalled to the hospital every 1 to 2 months for radiological and prosthetic review. When bone regeneration occurs, the cavity reduces in size and the tooth continues to erupt, the prosthodontist carefully reduces the intra-cystic length of the obturator, but the diameter at the opening is fully maintained.[76,79] The ultimate decision to terminate the use of the obturator is made by an oral surgeon based on assessment of radiographic images.[78]

Factors associated with effects of marsupialisation

Factors potentially influencing the effects of marsupialisation

There are various factors to consider when performing marsupialisation, such as patient age, size and location of cystic lesions, and patient cooperation.[70] The factors influencing the eruption of the DC-associated tooth after marsupialisation include cusp depth, angulation, eruption space, root formation and patient age.[14,15,57] A tooth with completely formed roots, that is severely displaced or that has insufficient eruption space cannot erupt spontaneously, and requires orthodontic traction if the impacted tooth is to be preserved.

Two-stage surgery

Marsupialisation can be performed alone or in combination with subsequent enucleation based on types of and postoperative changes in cystic lesions. Tomomatsu et al[82] evaluated the 3D changes that occurred in cystic lesions of the mandible after marsupialisation, and found that the effect of marsupialisation on cystic lesions with a major axis of 3 cm or more showed a significant difference between 3.0 and 4.5 months; however, the difference was not significant between 4.5 and 6.0 months. An indication for the timing of enucleation after marsupialisation would be 4.5 months when the rate of decrease of the cysts after fenestration slows down. However, Bodner et al[63] recommended that cysts be enucleated at 3.0 months after marsupialisation based on CT with multiplanar reconstruction in 23 patients treated with marsupialisation.

Two-stage surgery is often carried out in the cases of OKCs and UAs in order to eliminate the residual lesion because of their aggressive character and high recurrence rate.[64,83-85] Sano et al[73] performed marsupialisation followed by enucleation, without extracting the involved second molar in UA of the mandible in a 13-year-old girl, with the intention to improve the patient's oral function. As a result, spontaneous eruption of the involved second molar and excellent occlusion were obtained without orthodontic treatment, and no tumour recurrence was documented over a follow-up period of 51 months.[73]

Eliminating the disadvantages of marsupialisation

The disadvantage of marsupialisation is the very long healing process and the necessity of regular follow-up appointments. Cooperation of patients and their parents is essential and plays a major role in clinical success.[55,58] The most serious disadvantage is that pathological tissue is left in place and the entire lesion is not examined histopathologically. This runs the risk of unrecognised benign or malignant neoplastic processes being left behind, or malignant transformation of the remaining cyst lining.[56] All these drawbacks may be eliminated when DCs in children and preadolescents are managed with enucleation (cystectomy) but with preservation of associated teeth and adjacent tooth buds as a single surgical procedure. Hauer et al[54] presented a retrospective case series of seven patients with 15 unerupted teeth associated with or adjacent to DCs treated using the uniform surgical protocol (cystectomy, preservation of cyst-associated teeth, without use of orthodontic traction,

primary wound closure). The mean age of patients was 9.0 ± 2.1 years. All teeth erupted spontaneously. They suggested that the cystectomy of DCs with preservation of associated teeth may be considered an alternative to marsupialisation in children and preadolescents; however, enucleation carries a risk of possible loss of developing tooth buds when the dental crown is sharply separated from the cystic wall.

Cyst enucleation with coronectomy of impacted teeth

There are different treatment options for cystic lesions associated with an impacted tooth, and cyst enucleation with the removal of the unerupted tooth is a common one. These lesions have the potential to grow to a significant size, resulting in displacement of the unerupted tooth and weakening of the jaw. If the extensive cyst is associated with mandibular teeth, this can complicate surgery, with the risk of inferior alveolar nerve injury from removal of either the cyst or the unerupted tooth where proximity to the inferior alveolar nerve is present. Removal of the intracystic impacted tooth is sometimes difficult due to limited access, increased risk of damage to vital structures or jaw fracture. In such cases, coronectomy is likely to reduce these risks due to its conservative nature.[17]

Coronectomy is an alternative procedure for extraction of an entire wisdom tooth to minimise the risk of temporary or permanent inferior alveolar nerve (IAN) neuropathy. It involves careful removal of the crown of the tooth while maintaining its roots.[86,87] The most common complication of coronectomy is root mobilisation. Cosola et al[87] reported the data and follow-up radiographs of 130 patients who underwent coronectomy of mandibular third molars. The roots migrated in a mesial or coronal direction in 31 patients; in four cases, they were removed because of patient preference.[87] The placement of a bone graft material in the coronectomy socket could significantly decrease the incidence of root migration requiring reoperation of the exposed roots and reduce the preexisting pocket depth distal to the second molar, especially in patients with mesioangularly or horizontally impacted wisdom teeth.[88]

Despite the increase in popularity of coronectomy as an adequate preventative technique for IAN protection, its use in conjunction with the management of DCs has not been widely reported in the literature. O'Riordan[89] described a Gorlin-Goltz patient who had undergone coronectomy and removal of an OKC of the mandibular left second premolar. Malden and D'Costa[90] first reported the use of coronectomy with removal of DCs. Performance of coronectomy for DCs is based on the principle that the cyst originates from the enamel-dentine junction. Therefore, removing the crown below the enamel-dentine junction completely removes the cyst at its origin.[90,91] Patel et al[91] presented a case series of 21 patients with DCs treated by coronectomy. One patient had permanent injury to the inferior dental nerve, but no mandibular fracture or recurrence of cyst was reported.[91]

A retrospective review of 68 patients was undertaken by Henien et al[17] in a single department where 73 teeth with associated DCs were treated by coronectomy, and found that one patient experienced permanent injury of the IAN, and no intraoperative mandibular fractures occurred. Four coronectomy roots required retrieval at 2, 4 and 20 months and 10 years after the initial surgery due to persistent surgical site infection and incomplete coronectomy with retained enamel and associated cystic tissue leading to symptoms.[17] The authors suggested coronectomy in conjunction with enucleation of DCs is an effective treatment when there is concern regarding IAN injury or jaw fracture from extraction, with minimal morbidity seen in both short- and long-term periods.[17]

Orthodontic eruption of impacted teeth

Indications for surgical-orthodontic treatment of impacted teeth

The two most recommended conservative options are marsupialisation and decompression, which offer the possibility of preserving the impacted tooth associated with cystic lesions of the jaws. The major advantages of marsupialisation are limitation of the extent of surgery, gradual shrinkage of the cystic volume, stimulation of osteogenesis and promotion of the eruption of lesion-associated teeth. It has been well established that the mean amount of time it takes teeth to erupt without carrying out orthodontic traction is approximately 3 months. Tooth eruption does not always occur spontaneously after marsupialisation or decompression, especially when there is not enough space to allow eruption or no favourable axis is available.[70,71,92] The factors influencing the eruption of the DC-associated tooth include cusp depth, angulation, eruption space, root formation and patient age.[14,15,57,74] The impacted tooth without complete root formation or with an open apex has considerable potential to erupt spontaneously in the normal position in the dental arch after marsupialisation.[60]

A tooth with completely formed roots, that is severely displaced or has insufficient eruption space cannot erupt spontaneously. The combined approach of marsupialisation and orthodontic traction is considered the best option for patients with cystic lesions if the impacted tooth is to be preserved.[93-95] Combined orthodontic-surgical techniques may help promote tooth eruption related to cysts. The goals of this combination are to achieve traction of the tooth associated to cysts, open or maintain space, and correct the tooth position after marsupialisation or decompression.[16] Complete eruption and alignment of impacted teeth by means of orthodontic appliances may take more than 3 years after marsupialisation in some complicated cases.[1,93]

Marsupialisation with orthodontic traction of impacted teeth

A multidisciplinary approach proved to be an effective modality in treating a large cyst associated with a deeply impacted tooth. Tsironi et al[96] presented a case of a DC with a deeply impacted mandibular first molar in an 11-year-old girl that was treated with combined surgical and orthodontic procedures. The roots of the impacted molar were completely developed with closed apices.[96] After clinical and radiographic evaluation, marsupialisation of the cyst was performed, and a molar attachment was bonded onto the buccal side of the impacted molar as part of a full orthodontic treatment with fixed appliances.[96] After 18 months of orthodontic traction, the molar was moved to a more advantageous position, and new bone apposition was observed at the site of the cystic lesion, then the molar was left to erupt spontaneously for 14 more months and a functional occlusion was finally achieved.[96] When a third molar is deeply impacted within the cyst cavity, a combined orthodontic-surgical procedure may reduce the risk of damage to the IAN.[16] This approach may facilitate extraction and also reduce the possibility of nerve damage and pathological fractures of the mandible.

Comprehensive orthodontic treatment combined with marsupialisation can also be used to treat patients with OKCs and AOTs, especially young, growing patients with impacted anterior teeth or premolars.[97,98] Baik et al[98] described successful orthodontic treatment combined with marsupialisation of a cyst in a 10-year-old girl who exhibited a mandibular OKC with an impacted left canine and first premolar, as well as congenitally missing bilateral mandibular second premolars. After marsupialisation of the OKC, the positions of the impacted teeth showed spontaneous improvement, along with a reduction in the size of the cyst.[98] Orthodontic traction of the impacted teeth was easily achieved by using a removable appliance.[98] After treatment, the affected teeth showed normal vitality and fully developed roots.[98] The sequential use of removable and fixed appliances enabled orthodontic traction of the impacted teeth.[98] The treatment outcome was stable 2.5 years after the end of treatment.[98] Erdur et al[97] reported the uneventful eruption of an impacted canine in an AOT treated with combined orthodontics and marsupialisation, with no evidence of recurrence 3 years after treatment.

Enucleation with orthodontic traction of impacted teeth

Cyst enucleation in combination with orthodontics has been successfully used to treat cystic lesions with impacted teeth. Francisquini et al[99] reported a rare case of bilateral DCs associated with impacted maxillary canines treated by enucleation in association with orthodontic traction in an 11-year-old girl. Cystic lesions were enucleated by dissection and curettage of the tissue capsule surrounding the impacted teeth. Concomitantly, two orthodontic brackets were bonded to the surface of the crowns of the impacted canines for traction. Surgical enucleation, traction and orthodontic treatment enabled positioning of the impacted canines in the dental arches, thus ensuring maintenance of the functional and aesthetic characteristics, and no recurrence of the cyst was confirmed over the 5-year follow-up period.

Currently, there is an absence of quantitative data on orthodontic eruption of impacted teeth in cystic lesions due to the limited number of reported cases (only case reports are available). The success rate of surgical-orthodontic treatment of impacted teeth for cystic lesions of the jaws and long-term function of the preserved teeth should be further investigated.

Summary and conclusion

Cystic lesions of the jaws may be either symptomatic or asymptomatic and can be found in routine clinical and radiological investigations. Early identification and management are important, as this may avoid potential negative sequelae including failure of eruption, impaction of associated and surrounding teeth, displacement of teeth, resorption of adjacent roots, destruction of bone, encroachment on vital structures and occasionally pathological fracture. Surgical treatment for cystic lesions depends on the size, location, patient age and perforation of the cortical layer, as well as proximity

to vital structures such as teeth, the inferior alveolar canal and the maxillary sinus. The standard treatment for cystic lesions is enucleation of the cyst with extraction of the impacted tooth, particularly the third molar, supernumerary or malformed tooth. Marsupialisation and decompression are widely accepted conservative surgical procedures for the primary treatment of certain cystic lesions of the jaw. These techniques can be used either as a single therapy or in combination with other treatment modalities to eliminate the residual lesion. In children and preadolescents, this form of therapy is considered the first option with the main goal of preserving lesion-associated teeth. A multidisciplinary approach, such as orthodontic treatment combined with marsupialisation, can be an effective treatment strategy for DCs, especially in growing patients with impacted teeth that are severely displaced or that have insufficient eruption space, where spontaneous eruption is not possible. Marsupialisation followed by enucleation, without tooth removal, can be undertaken as a treatment option to obtain functional occlusion in some cases of OKCs, UAs or AOTs with impacted teeth; however, strict follow-up is necessary due to the possibility of recurrence. When unerupted third molars are involved, cyst enucleation with coronectomy can be a solution if the lesion is extensive and teeth are deeply impacted.

In conclusion, it is suggested that the management of impacted teeth associated with cystic lesions of the jaws should involve individualised treatment based on the characteristics of impacted teeth (position, root formation stage, angulation and depth of inclusion), type and size of the lesion, and the age of the patient.

Conflicts of interest

The authors declare no conflicts of interest related to this study.

Author contribution

Dr Yan Fang SUN contributed to the data collection and manuscript draft and revision; Drs Qian Ling WANG and Zhuo Yue SHI contributed to the data collection; Dr Yi ZHAO supervised the study and contributed to the manuscript revision.

(Received Apr 09, 2024; accepted Sep 19, 2024)

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