ODOVTOS
International Journal of Dental Sciences
https://revistas.ucr.ac.cr/index.php/Odontos | ISSN: 2215-3411

REVIEW AND CASE REPORT

DOI: 10.15517/ijds.2023.55127

Received:
9-III-2023

Accepted:
25-IV-2023

Published Online:
15-V-2023

Odontogenic Keratocyst Treatment Modalities. A Narrative Review and Case Report

Modalidades de tratamiento del queratoquiste odontogénico. Revisión de literatura con reporte de caso

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ABSTRACT: The odontogenic keratocyst (OKC) is a benign lesion that arises from dental lamina remnants or basal cells of the overlying epithelium. In 2005, the World Health Organization categorized OKCs as tumors due to their aggressive behavior. However, in 2017 due to the lack of evidence, it was reclassified as an odontogenic cyst with aggressive behavior. This report describes a clinical case of a 20-year-old male who visited the dental clinic at the University of Costa Rica for third molar removal. As an incidental radiographic finding, an intraosseous lesion in the right side of the mandible was detected. The patient was asymptomatic, with an augmented mass in the right posterior sulcus and crepitation at palpation. Decompression, enucleation followed by peripheral ostectomy, and incisional biopsy were performed, and a personalized and handmade acrylic appliance was fitted into the surgical window until it closed. No recurrence has been documented after 6 years. The continuous debate regarding OKC's classification by the WHO challenges the odontology community to constantly update its knowledge in the treatment modalities, taking into consideration the availability of resources and recurrence rates. The aim of this paper is to present the treatment and long-term follow-up of an OKC management and concomitantly review its main treatment options.

KEYWORDS: Case report; Decompression; Management; Odontogenic keratocyst; Osteotomy; Recurrence; Treatment.

RESUMEN: El queratoquiste odontogénico (OKC, siglas en inglés) es una lesión benigna derivada de los remanentes de la lámina dental o de las células basales del epitelio de revestimiento. En el 2005, la Organización Mundial de la Salud (OMS) clasificó los OKCs como tumores debido a su comportamiento agresivo. Sin embargo, en el 2017 por falta de evidencia, fue reclasificado como un quiste odontogénico con comportamiento agresivo. Este reporte describe el caso de un hombre de 20 años que visitó la clínica dental de la Universidad de Costa Rica para la remoción de las terceras molares. Como un hallazgo incidental radiográfico, se detectó una lesión intraósea en el lado derecho de la mandíbula. El paciente era asintomático con una masa aumentada en el reborde alveolar posterior derecho con crepitaciones a la palpación. Se realizó descompresión, enucleación seguidas por osteotomía periférica y una biopsia incisional; además, un dispositivo de acrílico personalizado y hecho a mano se ajustó en la ventana quirúrgica hasta que se logró un cierre. No hay recidiva documentada después de 6 años. El continuo debate de la clasificación del OKC por la OMS reta a la comunidad odontológica a una constante actualización sobre el conocimiento de las modalidades de tratamiento, tomando en cuenta la disponibilidad de recursos y las tasas de recidiva. El objetivo de este artículo es presentar el tratamiento y seguimiento de un OKC y concomitantemente revisar las principales opciones de tratamiento.

PALABRAS CLAVE: Reporte de caso; Descompresión; Manejo; Queratoquiste odontogénico; Osteotomía; Recidiva; Tratamiento.

INTRODUCTION

Philipsen introduced the odontogenic keratocyst (OKC) in 1956 (1). The OKC is a benign but aggressive intraosseous lesion that arises from dental lamina remnants or basal cells of the overlying epithelium. OKCs account for 8-11% of odontogenic cysts in patients over a wide age range, especially in males between the second and third decade (1,2). In addition, cysts are lined by parakeratinized or orthokeratinized epithelium, the second exhibiting a lower recurrence incidence (3). In contrast, the parakeratinized OKCs appear more aggressive (4). However, in the 4th edition of the World Health Organization (WHO) Classification of Head and Neck Tumors- Odontogenic and Maxillofacial Bone Tumors published in 2017, the orthokeratinized odontogenic cyst (OOC) was recognized as an odontogenic cyst distinct from OKCs (5).

OKCs are characterized as asymptomatic, slowly growing cysts with a high recurrence rate, aggressive clinical behavior, and association with the nevoid basal cell carcinoma syndrome (NBCCS) (2,6). These lesions can occur in a sporadic or solitary fashion or as part of the NBCCS. Among its clinical features, the expansion of the buccal and lingual cortical plates and the involvement of the inferior alveolar nerve occur late (3,4). Usually, OKCs are detected only by incidental radiographic findings but can be shown as symptomatic, with swelling and intra-oral drainage as common indicators. In addition, OKCs show an apparent predilection for the posterior body of the mandible and the ramus, although they can be diagnosed in any part of the jaw. Radiographically, they are described as unilocular or multilocular radiolucency with uniform sclerotic borders, associated or not with an unerupted tooth. Nonetheless, definitive diagnosis relies on histological examination (1,2).

In 2005, the WHO reclassified the OKC as a keratocystic odontogenic tumor (KCOT) due to their aggressive growth, recurrence rate, the rare occurrence of a "solid" variant of OKC, and mutations in the PTCH, CDKN2A, MCC, CADMI, FHIT, Ki-67 and p53 genes, which are commonly neoplasia-associated immunohistochemical markers. Since the PTCH mutations cause the NBCCS, it is predictable that the OKCs described in patients with this syndrome also show the mutation. NBCCS, known as Gorlin-Goltz or Gorlin syndrome, is a multisystem disease with high penetrance in an autosomal dominant fashion and variable expressivity (2-5).

However, in the WHO's 2017 classification, the KCOT was moved back to the cyst category and renamed OKC. This decision was made based on the current lack of evidence that classified the OKCs as neoplastic. In the fifth current classification, made in 2022, OKCs remain as cysts. Despite that, the debate continues (5,6). This case report and narrative review aim to present the treatment and long-term follow-up of an OKC and concomitantly review its main treatment options.

CASE REPORT

This literature review and case report was conducted following the Case Report Guidelines (CARE) (7) and carried out through a strategic search via MEDLINE (PubMed) electronic database and a hand search carried out from inception to January 2023 using the participants, interventions, comparator, and study design (PICOS) approach. The search strategy was devised as (P): patients with OKC, (I): decompression/marsupialization of OKC, (C): other surgical treatments of OKC, (O): recurrence rate, (S): guidelines, observational studies, randomized controlled trials, non-randomized controlled trials, systematic reviews, and meta-analysis from 1995-2023 with no language restrictions. Since this is a literature review and not a systematic review, there was no selection, elimination, and final inclusion of the studies as PRISMA guidelines suggest.

In 2016, a 20-year-old male with no hereditary or systemic medical conditions of relevance (ASA I) came to the Faculty of Dentistry of the University of Costa Rica with a chief complaint of third molar (3M) removal. An orthopantomography (OPG) was obtained as the protocol for the surgical procedure. After the OPG was taken, a clinical facial exam was made with no pathological findings. During the intraoral exam, an augmented mass at the right posterior sulcus and its ipsilateral retromolar area was encountered, with crepitation at palpation and no other mucosal alterations. The patient was asymptomatic and presented pulp vitality of mandibular second and first right molars. The mandibular right third molar was not clinically visible.

During the OPG analysis, a radiolucent lesion associated with unerupted tooth 4.8 was detected as an incidental finding. It was on the right side of the mandible, involving the body, angle, and part of the ascending ramus. The lesion exhibited an oval shape and well-defined corticated borders. Effects in the surrounding structures included expansion of the anterior border of the ascending ramus and displacement of the right inferior alveolar nerve canal in an inferior direction (Figure 1). For further evaluation, a CBCT scan was performed.

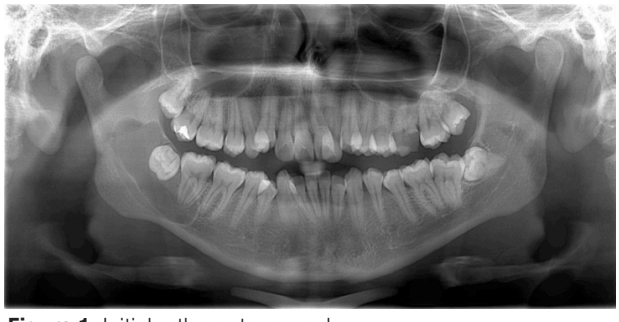

Figure 1. Initial orthopantomography.

The CBCT image showed the transverse position of unerupted tooth 4.8, with the crown facing the lingual cortical plate. The dimensions of the lesion were assessed, showing a width of 45.59mm, a height of 18.82mm, and a thickness of 12.44mm. The 3D evaluation also evidenced discreet expansion and thinning of the lingual cortical plate of the mandible and loss of the lamina dura in both roots of tooth 4.7. The lesion was in direct contact with the mandibular canal, causing erosion of its upper cortex (Figure 2).

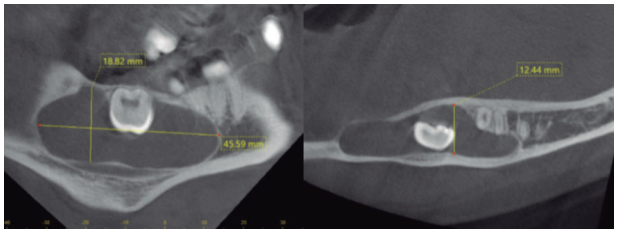

Figure 2. Initial CBCT.

Given the lesion's shape, which grew along the internal aspect of the bone with a scarce expansion of the lingual cortical plate, the radiological diagnosis considered was OKC (Figure 3).

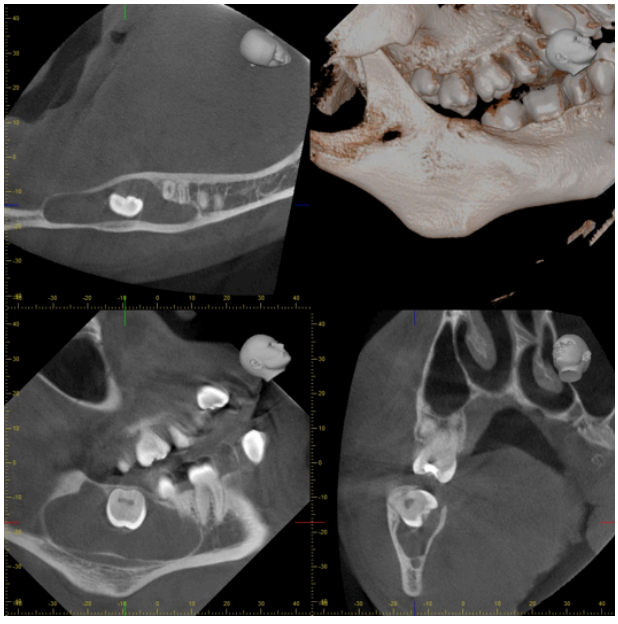

Figure 3. Tangential and axial CBCT views of the lesion, with its measurements.

A thorough explanation of the possible diagnoses was presented to the patient, which included the following: 1. Odontogenic keratocyst, 2. Unicystic ameloblastoma, 3. Dentigerous cyst. Decompression with enucleation and ostectomy of the lesion cavity and excisional biopsy under local anesthesia were recommended for initial management due to the size of the lesion (<5cm). Subsequently, an informed consent was signed by the patient, and a mucoperiosteal 3cm oval window over the retromolar mucosa was elevated. The cyst's overlying bone was removed with a #10 round tungsten carbide burr. A cyst sample was obtained from within the pathological cavity, and the lining was then identified and sutured to the oral mucosa, as described by Pogrel & Jordan, 2004 (8). As a surgical finding, 1.5-2ml of a whitish exudate was obtained. A continuous mattress suture was performed within the limits of the window created to prevent first intention healing of its mucosa. A personalized and handmade acrylic appliance was fitted into the window in a divergent manner, thus preventing mechanical retention of the device and facilitating its removal for hygienic purposes.

The biopsy sample was carried out to the pathologist, where it was found a cystic formation, whose wall was made up of dense fibro-connective tissue, with foci of acute and chronic inflammation which focally extended to the squamous epithelium covering the cyst. This squamous epithelium had 3 to 7 cell layers. Cells in the basal layer exhibited a palisade arrangement, and there was keratinization on the surface of the epithelium, with parakeratosis. In some areas the epithelium was detached from the connective tissue of the wall, no cytological atypia was observed in any area of the epithelium. There were reactive changes associated with an inflammatory process. The histopathological picture signs were compatible with an odontogenic keratocyst. No satellite cysts were observed in the connective tissue (Figure 4).

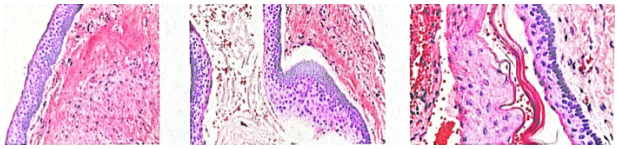

Figure 4. Histopathological sections of the lesion.

Once the definitive diagnosis was established, the patient was instructed to remove the acrylic appliance and rinse the pathological cavity using a needleless syringe with chlorhexidine 0,12%. A sequence of appointments was scheduled weekly and monthly for proper clinical follow-ups, an OPG was taken four months postoperatively. The acrylic device was reshaped in each appointment as the pathological cavity shrunk, and the window was almost closed six months after the initial surgical approach.

The post-surgical OPG showed the absence of tooth 4.8, loss of the cortical borders of the lesion, and partial bone repair, with bone showing sparse trabeculation (Figure 5).

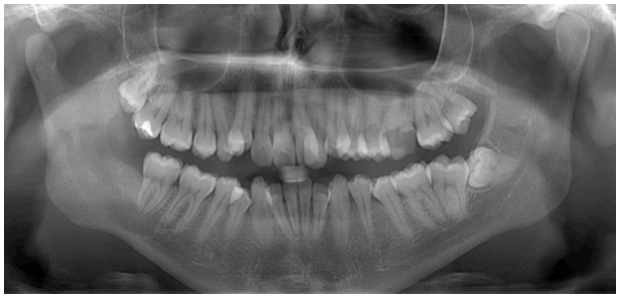

Figure 5. 4-month post-surgical OPG.

In the follow-up, CBCT image signs of bone repair were observed, including loss of the corticated borders, bone filling from the periphery towards the center of the defect, with frosted glass appearance. In addition, restitution of the lamina dura in tooth 4.7 was also noticed (Figure 6).

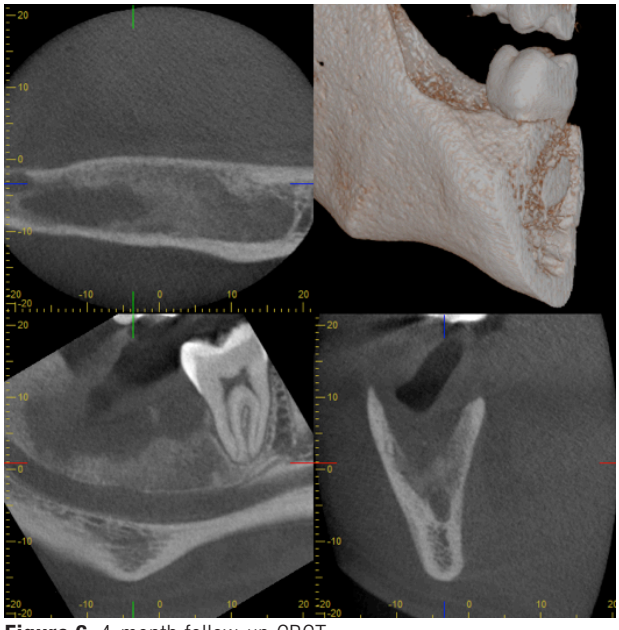

Figure 6. 4-month follow-up CBCT.

Unfortunately, the patient discontinued follow-up after 6 months but was successfully contacted six years later. After six years of initial surgical approach, the patient came back for a follow-up appointment. CBCT and OPG were taken. Clinically extraoral and intraoral exams did not show any pathological findings.

In the OPG, a complete bone repair of the defect is appreciated. The anatomical cortex corresponding to the oblique ridge was reestablished (Figure 7).

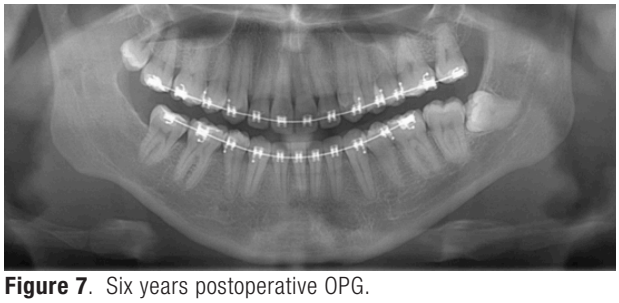

Figure 7. Six years postoperative OPG.

CBCT scan six years following the procedure showed a regular trabecular pattern in the area and restitution of the upper cortex of the inferior alveolar nerve canal in most of its length. No signs of recurrence were detected (Figure 8).

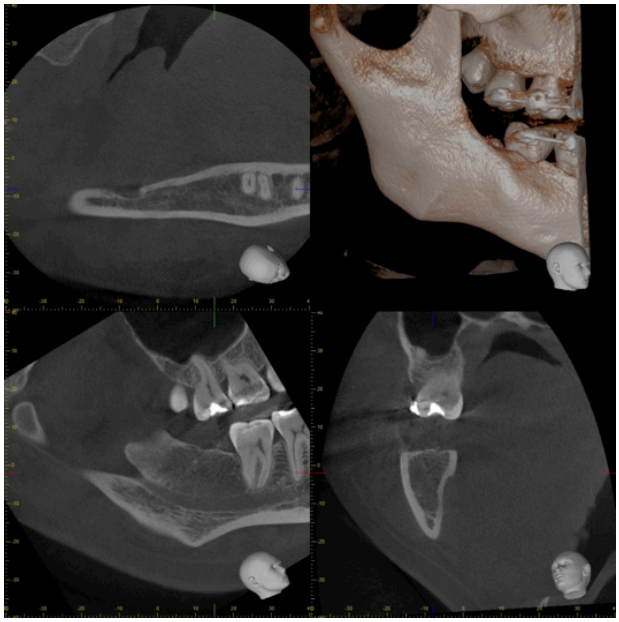

Figure 8. Six years postoperative CBCT.

DISCUSSION

The OKCs have been well characterized histologically by a thin, uniform lining of parakeratinized stratified squamous epithelium with a fibrous capsule. In 1981, Wright identified an orthokeratinized variant. In the first two editions of the WHO, this modification of OKCs was considered part of the same cyst. In 2005, with the reclassification in the 3rd edition of the WHO as KCOT, the orthokeratinized version was excluded, even though it was not classified as a different lesion. By the 4th edition, the OOC was introduced as a new jaw cyst (2,6,9).

The OOC is formed by a fibrous capsule lined by a uniform epithelium 4 to 8 cell layers deep, covered by a thick layer of orthokeratin, with a basal layer that tends to be of cuboidal or flattened cells but not palisaded and hyperchromatic. Meanwhile, the OKC is lined by a parakeratin epithelium with a basal layer formed by columnar or cuboidal cells. In contradistinction to OKCs, OOCs are not reported to have aggressive behavior; it is also not associated with the NBCCS and does not have a significant recurrence rate (5,10). For instance, in a systematic review submitted by MacDonald-Jankowski, 2010 (9), the comparison of recurrence rates was up to 28% in the OKC vs. 4% in the OOC.

Numerous characteristics make OKCs particular from the rest of jaw cysts, such as its well-documented aggressive behavior. Various gene mutations and neoplasia-associated immunohistochemical markers are expressed in OKCs, but there are distinct differences in the proliferative activity that suggests an alteration of the cell's cycle control. OKCs have an epithelial lining with intrinsic growth potential and a marked tendency to recurrence. A p53 gene mutation is identified in most of the basal cells of OKCs. It may be one of the causes of cell proliferation that potentially influences the biological features of the cyst's epithelium. Along this line, the expression of proliferating cell nuclear antigen (PCNA) in OKC´s basal and parabasal cells indicates that the p53-positive cells are actively dividing. Ki67 is also a proliferating cell marker. Its high expression in OKCs epithelium, and the correlation with PCNA reinforce the concept that these markers are expressed more strongly in OKCs than in other odontogenic cysts (11-13).

A significant characteristic is the lack of bony expansion in its initial phases. OKCs enlarge in the cancellous bone to a considerable size before any significant buccal or lingual expansion, growing in an anteroposterior direction, particularly at the angle of the mandible and ascending ramus. OKCs tend to hollow out the mandible, thereby replacing the bone marrow, rather than giving rise to the periosteal bone formation that would alert

patients and clinicians with bone swelling. Donoff *et al*. in 1972 demonstrated collagenase activity in keratocyst epithelium which appears to relate to the ability of OKCs to grow expansively within the medullary spaces of the bone (14-16). Shear, 2002 (17) supports the collagenolytic activity in OKCs and its influence on the expansion of cysts within the bone. Since keratinocytes had been shown to synthesize interleukin 1 (IL-1) and interleukin 6 (IL-6), OKCs release these cytokines in its epithelium and have potent bone resorbing properties; additionally, it was proposed that the expression of Interleukin 1α (IL-1α) was the principal osteolytic cytokine produced by OKCs leading to bone resorption. Likewise, the expression of the parathyroid hormone-related protein (PTHrP) might modulate growth and bone resorption in odontogenic cysts.

On the other hand, metalloproteins (MMPs) are related to participating in physiological tissue remodeling and pathological tissue destruction. While investigating the activation/inhibition profiles of MMPs, MMP-1 and MMP-9 were reported to be present in jaw cysts tissue extracts in latent and activated forms. Due to the presence of IL-1α secreted from keratocyst epithelial cells, the total activity ratio of MMP-9 (83-kDa MMP-9 and 92-kDa MMP) was significantly higher in OKCs fluids than in other cysts fluids, demonstrating that the IL-1α-dependent mechanism is involved in the cyst expansion and reinforcing the collagenolytic activity in OKCs via interaction with MMP-9 (17,18).

Furthermore, OKCs present remarkable recurrence rates from as low as 2.5% to as high as 62.5%, with most recurrences presenting within five years of treatment. Myoung *et al*., 2001 also reported the frequency of recurrence after surgical intervention to vary from 2.5% to 62.5%, suggesting that OKCs have shown higher recurrence rates depending on the chosen course of treatment (19-21).

The exact mechanism of this high recurrence remains unclear. However, there have been several attempts to explain its aggressive behavior and reappearance. For instance, OKCs can be correlated with the production of collagenase, prostaglandins, and highly active oxidative enzymes. Additionally, there have been demonstrated proliferating areas in different parts of the OKC epithelium and of the connective tissue wall suggesting that it probably resulted from the active growth of this wall. Other possible explanations are increased fibrinolytic activity in the cyst wall, increased mitotic activity, epithelial proliferation in connective tissue, and residual dental lamina with subsequent new cyst formation (21). Along with this theory, Pogrel, 2013 (3) presents three possible reasons for OKCs recurrence rate, the thin lining, which is friable and portions are easily left behind; daughter cysts occurring beyond the visible margin of the lesion; and some OKCs may originate from the oral mucosa and daughter cysts are seen between the oral mucosa and the cyst itself.

Daughter or satellite cysts are detached microcysts budding the basal layer into the underlying connective tissue. Daughter cysts are found beyond the cyst's lining and between the cyst and the alveolar mucosa (3,22). Pavelic, 2014 (14) selected 443 cases diagnosed as OKC, in which 88 (20.09%) cases presented satellite cysts. Since these microcysts are not found in other jaw cysts, they become a specific histological feature of these lesions. There is no consensus if daughter cysts may result in higher recurrence, while Myoung *et al*., 2001 (21) showed that one or more daughter cysts have a statistically significant

higher recurrence rate; studies like Ahfors *et al.*, 1984 suggest that there is no correlation. Moreover, Browne and Miller, 1969 reported a similar recurrence rate following the removal of OKCs with or without satellite cysts (23,24).

CLINICAL PRESENTATION OF ODONTOGENIC KERATOCYSTS

Due to the tendency of OKCs to extend into the medullary cavity of the bone, these cysts are mainly discovered incidentally during the review of routine dental radiographs. Patients are most presented as painless and remain asymptomatic until the maxillary sinus or the entire ascending ramus, including condylar and coronoid processes, are compromised. Even very large OKCs may still be symptomless, despite showing significant involvement of cortical bone and surrounding structures. However, pain, swelling, and discharge may be associated with OKCs (16,19,25). Stoelinga, 2001, in his study of 82 patients, reported 31 asymptomatic cases and 51 cases with swelling or inflammation (17 and 34, respectively). Though Morgan *et al.*, 2005 have reported 50% to 67% of OKCs to be symptomatic at the time of diagnosis, suggesting that when symptomatic, OKCs are larger, more destructive, and more challenging to treat (14,26).

NEVOID BASAL CELL CARCINOMA SYNDROME

The NBCCS is a rare autosomal dominant disorder with a prevalence of 1 in 57000-164000, it is a condition of high penetrance and variable expressivity. The syndrome is characterized by cutaneous, dentofacial, skeletal, ophthalmologic, and neurological anomalies. OKCs are one of the most consistent features of NBCCS, occurring in 65%-75% of cases, and may be presented as the first sign of NBCCS, arising earlier and with more recurrence rate than non-syndromic patients. Therefore, clinicians should consider NBCCS in all cases of OKCs, especially multiple OKCs coinciding or one after the other (19,23,27,28).

RADIOGRAPHICAL FEATURES OF ODONTOGENIC KERATOCYSTS

The radiographic aspects of OKCs are not pathognomonic and can be like other odontogenic cysts and tumors. Nevertheless, OKCs present a well-defined radiolucent lesion with smooth and usually corticated margins. Likewise, it appears as a multilocular or unilocular radiolucency with a scalloped contour that can occupy a significant part of the jaw without appreciable cortical expansion. Maxillary lesions involve adjacent structures more frequently than mandibular cysts, even though OKCs are most common in the mandibular molar-ramus region (15,19,29).

Regarding the effects of the OKC in surrounding structures, a systematic review described buccolingual expansion in 61% of the cases, association with an unerupted tooth in 35%, and root resorption in 23%. The radiographic features of the surgical site after the removal of benign lesions have been studied in 2D and 3D images (30,31). The radiographic findings expected in follow-up images include changes in the surgical site's periphery and interior. The cortical border of the lesion shows a progressive decrease in width and clarity and finally disappears over the months. In the surgical site's interior, bone formation in the periphery is expected, first with a ground glass appearance, followed by a spicular pattern. Finally, regeneration of the surgical site with normal bone trabeculae should be seen. The distance from the lesion site and the adjacent structures, like teeth or the mandibular canal, can also be assessed. This distance is expected to increase as healing advances. The integrity of the cortical bone in the surrounding areas should also be considered. A progressive remodeling of these anatomic cortices is expected. Kawai *et al.*, 1995 recom-

mends performing the first follow-up radiographic examination four months after surgery to verify proper bone healing; thus, this follow-up period was selected in this case report. The radiographic signs of bone healing described in the literature were confirmed in the follow-up OPG and CBCT images of this case report, indicating a positive outcome of the treatment (30-32).

TREATMENT MODALITIES/ STRATEGIES

The treatment of OKCs remains controversial as WHO debate regarding the lesion's classification stays open (6,26). Consequently, there has yet to be a consensus concerning the best management of OKCs. The surgical approaches range from conservative to more aggressive treatments. Conservative treatment is "cyst-oriented" and consists of enucleation, with or without curettage, marsupialization, and decompression. Alternatively, aggressive treatment addresses the "neoplastic nature" that OKCs tend to express and includes peripheral ostectomy, resection, chemical curettage with Carnoy's solution, or liquid nitrogen. Treatment choice should rely upon various factors, including patient age, size, cyst location, soft tissue involvement, and previous treatment history. The goal is to choose the treatment modality with the lowest possible risk of recurrence and the least morbidity while eradicating the lesion (33-35).

ENUCLEATION

To enucleate means to remove whole or clean; it consists of completely removing OKC from the bone cavity without leaving any visible remnants of the lesion (34). The primary advantages of enucleation are the complete removal of the cyst and a thorough histopathologic examination of the lesion. However, this treatment modality alone presents the highest rates of recurrence (as high as 62.5%) and is no longer an acceptable course of treatment (34,36,37). Pogrel, 2013 described a rate from 25% to 60% following simple enucleation. Along these high rates, Morgan *et al.*, 2005 observed a recurrence of 54.5%. Nonetheless, Zhao *et al.*, in a 2012, study found a recurrence rate of 7.4% by enucleation alone done in 257 patients; the same author observed in a 2002 study a rate of 17.79% following enucleation alone in 163 OKCs (3,24,26,37).

Additionally, it may compromise the vitality of adjacent anatomic structures. The complete eradication of the lesion is necessary to decrease or eliminate recurrences, so OKCs' friable and thin lining is easily fragmented during excision. Moreover, satellite cysts may be left beyond the enucleated cysts in the overlying mucosa adjacent to the cyst, especially in multilocular lesions (34,36,37).

ENUCLEATION AND CURETTAGE (E&C)

Curettage is the surgical scraping of the wall of a cavity within the soft tissue or bone to remove its contents. Enucleation associated with curettage is a conservative and effective option with low morbidity, although it results in a high recurrence rate. For example, Dashow *et al.*, 2015 refer to simple enucleation and curettage excluding Carnoy's Solution (CS) with 27.8% and 30.8% recurrence rates. Maurette *et a*l.,2006 reported a 20% of recurrence, while Chirapathomsakul *et al.*, 2006 described recurrence in both OKCs treated with E&C. This strategy has the advantage over marsupialization of providing a complete specimen for histopathologic analysis, and it might be considered the minimal requirement to treat an OKC. Nevertheless, this modality may present difficulties in the procedure due to the thin lining to adjacent bone or soft tissue that may result in an incomplete enucleation of the lesion (15,29,36,38-40).

MARSUPIALIZATION AND DECOMPRESSION

Decompression involves any technique that relieves the pressure within the cyst that causes it to grow. It can be performed by making

a small opening in the cyst and keeping it open with a drain. However, marsupialization consists of opening the cyst to the oral cavity and suturing the cyst lining to the oral mucosa, creating a permanent opening into the cyst; therefore, the lesion is decompressed and decreased in size as new bone is laid around it (3,41). Every marsupialization is a decompression; nonetheless, it is not the contrary.

Marsupialization is carried out by decompressing a cyst and drawing off the fluid with a syringe and needle, then creating a surgical window in the oral mucosa and cyst membrane and using a cylindrical device or a rigid surgical drain to prevent mucosa closure, converting the cyst into a pouch (8,29). As a result, marsupialization reduces the cystic volume and lessens the chance of injury to critical anatomical structures like the inferior dental nerve. In addition, it appears that OKCs may respond more rapidly and predictably to marsupialization and decompression than other odontogenic cysts due to the reduction of the positive intracystic pressure and its association with inhibiting IL-1α expression. It also decreases epithelial cell proliferation, essential in regulating the OKC's growth, and thickens the cystic wall after the procedure. Meanwhile, reducing the size of the cystic cavity promotes new bone formation in a centripetal direction (8,42,43).

Possible disadvantages of marsupialization and decompression are that the time necessary for the treatment is long, and it may take much work to obtain a representative biopsy through the small opening. Along these aspects, both treatments require the patient's cooperation to irrigate the cyst regularly, limiting the treatment to only a suitable group of patients (8,37).

Pogrel 2013, reported a 5% recurrence rate after using marsupialization for complete resolution. In comparison, Dashow *et al.*, 2015 reported marsupialization alone at a rate of 18.2%, Chirapathomsakul *et al.*, 2006 described a 16.7% rate, and Madras & Lapointe, 2008 stated a 0% rate. (3,15,35,38).

DECOMPRESSION WITH ENUCLEATION

Decompression followed by enucleation can reduce the high recurrence rates after a certain period. Zhao *et al.*, 2002 in a retrospective analysis of 255 patients, treated 11 cases with this technique and found a 0% recurrence vs. 17,79% (29 out of 163 cases) of recurrence with enucleation alone. However, Cunha *et al.*, 2017 reported a 21.4% of recurrence rate, and Kolokythas *et al.*, 2007 described a rate of 14.3%. This strategy is advantageous in cases of large cysts, reduced OKCs small enough to be eradicated, and cases where the cyst size has not decreased significantly. Decompression with enucleation reduces the complications associated with enucleation alone when the procedure is done after a notorious reduction in the cystic lumen. After the decompression treatment, the epithelial cyst lining undergoes metaplasia, becomes thicker, and may resemble normal oral mucosa, allowing the cyst enucleation to be a safer intervention (33,34,37,44-46).

CARNOY'S SOLUTION

CS was first described in 1933; it is a fixative solution that kills vital OKC daughter cells, epithelial islands, and cell remaining in the cyst cavity at the lesion periphery. This solution contains ethanol, chloroform, glacial acetic acid, and ferric chloride. The U.S Food and Drug Administration (FDA) banned CS in 2013 due to the chloroform contained in it, labeled as "reasonably anticipated to be a human carcinogen," which led to substitute CS to a non-chloroform version: modified Carnoy's solution (MC). Dashow et al., 2015 compared the recurrence rates between E&C followed by CS (10%) vs. E&C followed by MC (35%) in a retrospective cohort study and found that OKCs are nearly seven times more likely to recur when treated with MC. Nonetheless, in a

retrospective cohort study, Donnelly *et al.*, 2021 found no significant difference in recurrence for OKCs based on a treatment by CS or MC after E&C and peripheral ostectomy, along with the different treatment modalities followed by CS, Morgan *et al.*, 2005 and Chirapathomsakul *et al.*, 2006 described enucleation alone with CS at recurrence rates of 50% and 20%, respectively. Morgan *et al.*, 2005 reported no recurrences after performing peripheral ostectomy with CS (15,26,38,47,48). CS is an aggressive treatment due to the possibility of causing irreversible neurotoxicity, toxicity to the adjacent soft tissue, skin, and dental follicles, irreversible damage to the superficial and devitalized osseous margin, and no possibility of immediate bone grafting. In addition, CS chemically fixes the inferior or lingual nerves if it comes in contact with them for up to 2 minutes; therefore, the nerves must be protected (3,34).

LIQUID NITROGEN CRYOTHERAPY

Theoretically, the ideal treatment for the OKC would be E&C followed by treatment of the cavity with an agent that would kill the epithelial remnants or satellite cysts. However, the osseous framework should be left intact to allow osteoconduction. Accordingly, liquid nitrogen can produce cellular necrosis in the bone while maintaining the inorganic osseous framework (34,49). Cell death with cryosurgical agents (liquid nitrogen) occurs by direct damage from intracellular and extracellular ice crystal formation plus osmotic and electrolyte disturbance by exposing the cyst cavity to temperatures below -20°C (36,48). The technique involves enucleation of the lesion, soft tissue protection with wooden tongue blades and dry gauze, and treating the cyst cavity with liquid nitrogen (3).

Moreover, the potential lack of precision with cryotherapy can injure hard and soft tissue (thermal trauma) and lead to pathological fractures by exposing of the bone to the freezing agent, as it penetrates at least 1.5mm around the cavity (3,34). Furthermore, the bone undergoes a significant reduction in mechanical strength eight weeks after cryotherapy; it is advisable to maintain a soft diet to avoid future complications. Cryotherapy can cause neurosensory changes if in contact with nerve structures. However, it has been shown that the neuron degenerates, but the axon sheath is intact, and nerve regeneration is good. Evidence shows that simple enucleation followed by liquid nitrogen cryotherapy may reduce the recurrence rate to 9% (3,41,48,49).

PERIPHERAL OSTECTOMY

This treatment modality is often combined with other strategies. For example, enucleation with peripheral ostectomy tries to solve the high recurrence rate of enucleation alone by removing 1 to 2mm of bone beyond the visible margin. Peripheral ostectomy is a mechanical method of removing remnant cells whereby the bony cavity is stained with methylene blue or crystal violet to reveal the remnant cells of the OKC (3,48). Then, the peripheral bone is reduced with a powered handpiece. Likewise, using CS in combination with peripheral ostectomy is another technique that may increase its safety margins and compensate for its deficiency when lesions are near soft tissue and between dental roots (26,50).

On the other hand, marsupialization or decompression of large cysts that have not perforated the cortical bone, followed by peripheral ostectomy with or without chemical treatment, has achieved reasonable success. For example, Morgan *et al.*, 2005 found that treatment of an OKC with peripheral ostectomy was associated with a low recurrence rate of 18.2%. Additionally, Kolokythas *et al.*, 2007 observed no recurrence combining patients treated by enucleation associated with peripheral ostectomy (26,33).

RESECTION

The reclassification of OKCs as an odontogenic cyst reinforces the choice of conservative treatments, but resection was a more prominent treatment strategy when it was considered a tumor. The bloc resection is indicated in cases of multiple recurrences or aggressive cysts; however, the morbidity associated, such as the loss of jaw continuity or facial disfigurement, makes surgeons choose more conservative strategies. Even though it offers the highest cure rate and 0% of recurrence rate, the question is whether the invasive nature of resection and reconstruction of the mandible or maxilla is acceptable given the benign nature of the lesion and the low recurrence rates associated with less invasive procedures (33-35,37,39,44,46,50).

A summary of OKC´s recurrence rates according to different treatment options was made. The description and association of each treatment modality with its respective recurrence was taken as the including criteria (Table 1).

The treatment strategy used in this case report was based on the stated recurrence rates and the availability of resources in the Faculty of Dentistry of the University of Costa Rica. The chosen treatment was decompression with enucleation followed by peripheral ostectomy; according to the evidence gathered, when decompression and enucleation are implemented simultaneously, the complications of the treatments alone significantly decrease. Adding an adjunctive therapy, such as peripheral ostectomy, along with this modality, improves the possibilities of a recurrence-free recovery. To this date, 6 years after the initial intervention, there are no clinical or radiological signs of recurrence. Clinical and radiological follow-up is advised for at least the first five years after the procedure due to the risk of recurrence of OKCs before this period.

Table I. Summary of recurrence rates according to the treatment strategies of OKCs in the papers of this narrative review.

Authors		n	Treatment Modality	Recurrence rate (%)
Boffano *et al.* (2)		120	Enucleation	24
		204	Enucleation and curettage/peripheral ostectomy	9
		38	Enucleation and CS	8
		12	Marsupialization	8
		7	Decompression with residual cystectomy	43
	n=415	3	Decompression without residual cystectomy	66
		5	Marginal resection	0
		3	Segmental resection	0
		9	Marsupialization & enucleation	22
		11	Marsupialization & enucleation and curettage/peripheral ostectomy	9
		2	Marsupialization & enucleation and CS	50
		1	Marsupialization & marginal resection	0
Stoelinga (14)		33	Enucleation	18
		6	Enucleation & excision of mucosa	0
	n=82	38	Enucleation, excision of mucosa & CS	7.8
		5	Enucleation & CS	0
Chirapathomsakul *et al.* (15)		6	Marsupialization	16.7
		15	Enucleation	13.3
	n= 35	5	Enucleation with CS	20
		2	Enucleation and curettage	100
		1	Marginal Resection	0
		6	Segmental Resection	16.7
Zhao *et al.* (24)	n=257		Enucleation	7.4
Fidele *et al.* (25)		274	Enucleation	17.52
	n=351	53	Marsupialization & enucleation	7.5
		24	Resection	4.17
Morgan *et al.* (26)		11	Enucleation	54.5
		2	Enucleation with CS	50
	n=40	11	Peripheral ostectomy	18.2
		13	Peripheral ostectomy with CS	0
		3	Resection	0
Maurette *et al.* (29)	n=30	20	Decompression and curettage	10
		10	Enucleation and curettage	20
Kolokythas *et al.* (33)		3	Resection	0
		8	Enucleation with peripheral ostectomy	0
	n=21	3	Decompression	33.3
		7	Decompression with enucleation	14.3

Authors		n	Treatment Modality	Recurrence rate (%)
Madras & Lapointe (35)		2	Resection	0
	n= 21	3	Marsupialization	0
		16	Curettage	31.25
Zhao *et al.* (37)		163	Enucleation	17.79
	n=255	29	CS with enucleation	6.7
		11	Decompression with enucleation	0
		52	Resection	0
Dashow *et al.* (38)	n= 80	44	Enucleation and curettage with CS	10
		36	Enucleation and curettage with MS	35
Pogrel (41)	n=20		Marsupialization/decompression	5
Cunha *et al.* (46)	n=24	10	Enucleation with peripheral ostectomy	50
		18	Decompression with enucleation	21.4
Donnelly *et al.* (47)	n= 77	36	Enucleation and curettage, peripheral ostectomy and CS	14.29
		41	Enucleation and curettage, peripheral ostectomy and MC	14.6
Motaleb *et al.* (48)		31	Enucleation	12
	n=56	6	Enucleation & CS	0
		2	Enucleation & mechanical debridement	0
		2	Enucleation & cryotherapy	0
		11	Decompression	0
		4	Decompression & CS	0
Schmidt & Pogrel (49)	n=26		Enucleation with cryotherapy	11.5

CS=Carnoy´s solution; MS=Modified Carnoy's solution; n=number of OKCs.

CONCLUSION

An exhaustive assessment of the papers covered in this case report and narrative review was made, aiming to create a summary of recurrence rates according to the treatment strategies of OKCs. The recurrence rates vary for each treatment. For instance, enucleation presented recurrences as low as 7.4% and as high as 54%, but when used with other adjunctive therapies, the recurrences differed from 0% to 100%. Marsupialization and decompression alone varied from 0% to 33.3%, and when used with another strategy, the rates were reported from 0% to 66%, depending on the chosen adjunctive therapy. Peripheral ostectomy alone was not commonly used; however, it only presented a recurrence rate of 18.2%, and when used in addition to other treatments, the rates were from 0% to 50%. Carnoy's solution and liquid nitrogen cryotherapy are used with different main treatments; usually, they accompany enucleation and marsupialization. CS varies from 0% to 50%, and liquid nitrogen cryotherapy goes from 0% to 19.5%. Resection presented 0% except for one case where the segmental resection recurred, representing 16.7% in its corresponding study.

This case presented the incidental finding of a mandibular OKC of considerable size and its successful management by decompression with enucleation and peripheral osteotomy. Six years of follow-up showed no recurrence of the lesion. The imaging modalities used were necessary, not only for the initial detection of a mandibular lesion

but for the thorough follow-up of the treatment, however the anatomopathological study is the only definitive diagnostic method for odontogenic cysts and tumors (6).

The multiple reclassifications that the OKC has undergone by the WHO should be taken with caution. It challenges the odontology community to constantly review the treatment modalities endorsed by up-to-date scientific evidence.

PATIENT CONSENT

Written consent was obtained from the patient.

FUNDING

No funding was sourced.

CONFLICT OF INTEREST

None of the authors declare any conflict of interest.

AUTHOR CONTRIBUTION STATEMENT

Conceptualization and design: M.E.M.P.
Literature review: M.E.M.P. and G.P.T.
Methodology and validation: M.E.M.P. and G.P.T.
Formal analysis: M.E.M.P., A.C.R.I. and G.P.T.
Investigation and data collection: M.E.M.P. and G.P.T.
Resources: M.E.M.P. and G.P.T.
Data analysis and interpretation: M.E.M.P., A.C.R.I. and G.P.T.
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ACKNOWLEDGEMENT

Dr. Diego Guillén Colombari MD. Pathologist and professor at the Diagnostic and Surgical Sciences Department, Faculty of Dentistry, University of Costa Rica.

REFERENCES

1. Li T.J. Critical reviews in oral biology & medicine: The odontogenic keratocyst: A cyst, or a cystic neoplasm? J Dent Res. 2011; 90 (2): 133-42.
2. Boffano P., Cavarra F., Agnone A.M., Brucoli M., Ruslin M., Forouzanfar T., et al. The epidemiology and management of odontogenic keratocysts (OKCs): A European multicenter study. J Cranio-Maxillofacial Surg. 2022; 50 (1): 1-6.
3. Pogrel M.A. The Keratocystic Odontogenic Tumor. Oral Maxillofac Surg Clin North Am. 2013 Feb; 25 (1): 21-30.
4. Carlson E.R., Oreadi D., McCoy J.M. Nevoid Basal Cell Carcinoma Syndrome and the Keratocystic Odontogenic Tumor. J Oral Maxillofac Surg [Internet]. 2015; 73 (12): S77-86. Available from: http://dx.doi.org/10.1016/j.joms.2015.04.037
5. Wright J.M., Vered M. Update from the 4th Edition of the World Health Organization Classification of Head and Neck Tumours: Odontogenic and Maxillofacial Bone Tumors. Head Neck Pathol. 2017; 11 (1): 68-77.
6. Soluk-Tekkesin M., Wright J.M. The World Health Organization Classification of Odontogenic Lesions: A Summary of the Changes of the 2022 (5th) Edition. Turk Patoloji Derg. 2022; 38 (2): 168-84.

7. Gagnier J.J., Kienle G., Altman D.G., Moher D., Sox H., Riley D.; the CARE Group. The CARE Guidelines: Consensus-based Clinical Case Reporting Guideline Development. BMJ Case Rep. 2013; doi: 10.1136/bcr-2013-201554 PMID: 24155002
8. Pogrel M.A., Jordan R.C.K. Marsupialization as a definitive treatment for the odontogenic keratocyst. J Oral Maxillofac Surg. 2004 Jun 1; 62 (6): 651-5.
9. MacDonald-Jankowski D.S. Orthokeratinized odontogenic cyst: A systematic review. Dentomaxillofacial Radiol. 2010 Dec; 39 (8): 455-67.
10. Da Silva M.J.A., De Sousa S.O.M., Corrêa L., Carvalhosa A.A., De Araújo V.C. Immunohistochemical study of the orthokeratinized odontogenic cyst: A comparison with the odontogenic keratocyst. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2002; 94 (6): 732-7.
11. Piattelli A. P53 protein expression in odontogenic cysts. J Endod. 2001; 27 (7): 459-61.
12. Boyne P.J., Hou D., Moretta C., Pritchard T. The multifocal nature of odontogenic keratocysts. J Calif Dent Assoc [Internet]. 2005 Dec [cited 2022 Oct 13]; 33 (12): 961-5. Available from: http://www.ncbi.nlm.nih.gov/pubmed/16454239
13. Shear M. The aggressive nature of the odontogenic keratocyst: Is it a benign cystic neoplasm? Part 2. Proliferation and genetic studies. Oral Oncol [Internet]. 2002 [cited 2022 Nov 5]; 38 (4): 323-31. Available from: https://pubmed.ncbi.nlm.nih.gov/12076694/
14. Stoelinga P.J.W. Long-term follow-up on keratocysts treated according to a defined protocol. Int J Oral Maxillofac Surg [Internet]. 2001 [cited 2022 Oct 13]; 30 (1): 14-25. Available from: https://pubmed.ncbi.nlm.nih.gov/11289615/
15. Chirapathomsakul D., Sastravaha P., Jansisyanont P. A review of odontogenic keratocysts and the behavior of recurrences. Oral Surg Oral Med Oral Pathol Oral Radiol Endod [Internet]. 2006 [cited 2022 Oct 13]; 101 (1): 5-9. Available from: https://pubmed.ncbi.nlm.nih.gov/16360602/
16. Shear M. Odontogenic keratocysts: clinical features. Oral Maxillofac Surg Clin North Am [Internet]. 2003 [cited 2022 Dec 4]; 15 (3): 335-45. Available from: https://pubmed.ncbi.nlm.nih.gov/18088687/
17. Shear M. The aggressive nature of the odontogenic keratocyst: Is it a benign cystic neoplasm? Part 1. Clinical and early experimental evidence of aggressive behaviour. Oral Oncol [Internet]. 2002 [cited 2022 Nov 5]; 38 (3): 219-26. Available from: https://pubmed.ncbi.nlm.nih.gov/11978543/
18. Kubota, Y., Ninomiya, T.,Oka, S., Takenoshita, Y., Shirasuna K. Interleukin- 1 a--dependent Regulation of Matrix Metalloproteinase-9 and Activation in the Epithelial Cells of Odontogenic Jaw Cysts. J Dent RES [Internet]. 2000; 79 (6): 1423-30. Available from: https://pubmed.ncbi.nlm.nih.gov/10890723/
19. Bhargava D, Deshpande A, Pogrel MA. Keratocystic odontogenic tumour (KCOT)-a cyst to a tumour. Oral Maxillofac Surg. 2012 Jun; 16 (2): 163-70.
20. Kinard B., Hansen G., Newman M., Dennis P., Haeffs T., Perez S., et al. How well do we manage the odontogenic keratocyst? A multicenter study. Oral Surg Oral Med Oral Pathol Oral Radiol. 2019 Apr 1; 127 (4): 282-8.
21. Myoung H., Hong S.P., Hong S.D., Lee J. Il, Lim C.Y., Choung P.H, et al. Odontogenic keratocyst: Review of 256 cases for recurrence and clinicopathologic parameters. Oral Surg Oral Med Oral Pathol Oral Radiol Endod [Internet]. 2001 [cited 2022 Nov 23]; 91 (3): 328-33. Available from: https://pubmed.ncbi.nlm.nih.gov/11250631/
22. Boiidar Pavelić, Marina Katunarić, Sanja Segović, Maja Cimas Karadole, Davor Katanec, Aida Saban IP. The incidence of satellite cysts in keratocystic odontogenic

tumors.:EBSCOhost[Internet].JOURNALOF THE CROATION ANTHROPOLOGICAL SOCIETY. 2014 [cited 2022 Nov 10]. p. Vol 38. 269-273. Available from: https://web-s-ebscohost-com.ezproxy.sibdi.ucr.ac.cr/ehost/pdfviewer/pdfviewer?vid=0&sid=e2bcca97-9577-4625-b34f-0a1a2ed18ce2%40redis

23. Raj A., Bahadur R., Bansal S., Kumar P. Intricate correlation and biological behavior of keratocyst in nevoid basal cell carcinoma syndrome: A comprehensive review of literature. Clin Cancer Investig J [Internet]. 2013 [cited 2022 Nov 23]; 2 (3): 185. Available from: https://ccij-online.org/article/intricate-correlation-and-biological-behavior-of-keratocyst-in-nevoid-basal-cell-carcinoma-syndrome:-a-comprehensive-review-of-literature-113
24. Zhao Y., Liu B., Cheng G., Wang S.P., Wang Y.N. Recurrent keratocystic odontogenic tumours: Report of 19 cases. Dentomaxillofacial Radiol. 2012 Feb 1; 41 (2): 96-102.
25. Fidele N.B., Yueyu Z., Zhao Y., Tianfu W., Liu J., Sun Y., et al. Recurrence of odontogenic keratocysts and possible prognostic factors: Review of 455 patients. Med Oral Patol Oral y Cir Bucal. 2019 Jul 1; 24 (4): e491-501.
26. Morgan T.A., Burton C.C., Qian F. A retrospective review of treatment of the odontogenic keratocyst. J Oral Maxillofac Surg. 2005; 63 (5): 635-9.
27. Bakaeen G., Rajab L.D., Sawair F.A., Hamdan M.A.M., Dallal N.D. Nevoid basal cell carcinoma syndrome: a review of the literature and a report of a case. Int J Paediatr Dent [Internet]. 2004 Jul [cited 2023 Jan 20]; 14 (4): 279-87. Available from: https://pubmed.ncbi.nlm.nih.gov/15242385/
28. Balasundram S., Kovilpillai F.J., Hopper C. Nevoid basal cell carcinoma syndrome presenting with neck pits and café au lait patches. J Clin Pediatr Dent [Internet]. 2010 Sep 1 [cited 2022 Oct 13]; 35 (1): 95-100. Available from: http://www.ncbi.nlm.nih.gov/pubmed/21189772
29. Maurette P.E., Jorge J., De Moraes M. Conservative treatment protocol of odontogenic keratocyst: a preliminary study. J Oral Maxillofac Surg [Internet]. 2006 [cited 2023 Jan 17]; 64 (3): 379-83. Available from: https://pubmed.ncbi.nlm.nih.gov/16487797/
30. Kawai T., Murakami S., Hiranuma H., Sakuda M. Healing after removal of benign cysts and tumors of the jaws. A radiologic appraisal. Oral Surgery, Oral Med Oral Pathol Oral Radiol. 1995; 79 (4): 517-25.
31. Bodner L., Bar-Ziv J. Characteristics of bone formation following marsupialization of jaw cysts. Dentomaxillofacial Radiol. 1998; 27 (3): 166-71.
32. MacDonald-Jankowski D.S. Keratocystic odontogenic tumour: Systematic review. Dentomaxillofacial Radiol. 2011 Jan; 40 (1): 1-23.
33. Kolokythas A., Fernandes R.P., Pazoki A., Ord RA. Odontogenic Keratocyst: To Decompress or Not to Decompress? A Comparative Study of Decompression and Enucleation Versus Resection/Peripheral Ostectomy. J Oral Maxillofac Surg. 2007 Apr; 65 (4): 640-4.
34. de Castro M.S., Caixeta C.A., de Carli M.L., Ribeiro Júnior N.V., Miyazawa M., Pereira A.A.C., et al. Conservative surgical treatments for nonsyndromic odontogenic keratocysts: a systematic review and meta-analysis. Clin Oral Investig. 2018 Jun 1; 22 (5): 2089-101.
35. Madras, Jonatha; Lapointe H. Keratocystic odontogenic tumour: reclassification of the odontogenic keratocyst from cyst to tumour - PubMed. J Can Dent Assoc [Internet]. 2008 [cited 2023 Jan 17]; 74 (2): 165-165h. Available from: https://pubmed.ncbi.nlm.nih.gov/18353202/
36. Giuliani M., Grossi G.B., Lajolo C., Bisceglia M., Herb K.E. Conservative management of a

large odontogenic keratocyst: report of a case and review of the literature. J Oral Maxillofac Surg [Internet]. 2006 Feb [cited 2023 Jan 21]; 64 (2): 308-16. Available from: https://pubmed.ncbi.nlm.nih.gov/16413905/

37. Zhao Y.F., Wei J.X., Wang S.P. Treatment of odontogenic keratocysts: A follow-up of 255 Chinese patients. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2002; 94 (2): 151-6.
38. Dashow J.E., McHugh J.B., Braun T.M., Edwards S.P., Helman J.I., Ward B.B. Significantly decreased recurrence rates in keratocystic odontogenic tumor with simple enucleation and curettage using carnoy's versus modified carnoy's solution. J Oral Maxillofac Surg [Internet]. 2015 Nov 1 [cited 2022 Oct 13]; 73 (11): 2132-5. Available from: http://dx.doi.org/10.1016/j.joms.2015.05.005
39. Blanas N., Freund B., Frcd C., Schwartz M. Systematic review of the treatment and prognosis of the odontogenic keratocyst. Oral Surg Oral Med Oral Pathol Oral Radiol Endod [Internet]. 2000; 90 (5): 553-8. Available from: https://pubmed.ncbi.nlm.nih.gov/11077375/
40. Boffano P., Ruga E. Keratocystic odontogenic tumor (odontogenic keratocyst): preliminary retrospective review of epidemiologic, clinical, and radiologic features of 261 lesions from University of Turin. J Oral Maxillofac Surg [Internet]. 2010; 68 (12): 2994-9. Available from: https://pubmed.ncbi.nlm.nih.gov/20970907/
41. Pogrel M.A. Treatment of keratocysts: The case for decompression and marsupialization. J Oral Maxillofac Surg. 2005 Nov; 63 (11): 1667-73.
42. Johnson N.R., Batstone M.D., Savage N.W. Management and recurrence of keratocystic odontogenic tumor: A systematic review. Oral Surg Oral Med Oral Pathol Oral Radiol [Internet]. 2013; 116 (4): e271-6. Available from: http://dx.doi.org/10.1016/j.oooo.2011.12.028
43. Ninomiya T, Kubota Y, Koji T, Shirasuna K. Marsupialization inhibits interleukin-1alpha expression and epithelial cell proliferation in odontogenic keratocysts. J Oral Pathol Med [Internet]. 2002 Oct [cited 2022 Nov 5]; 31 (9): 526-33. Available from: https://pubmed.ncbi.nlm.nih.gov/12269991/
44. Tolstunov L., Treasure T. Surgical Treatment Algorithm for Odontogenic Keratocyst: Combined Treatment of Odontogenic Keratocyst and Mandibular Defect With Marsupialization, Enucleation, Iliac Crest Bone Graft, and Dental Implants. J Oral Maxillofac Surg. 2008 May; 66 (5): 1025-36.
45. Slusarenko da Silva Y., Stoelinga P.J.W., Naclério-Homem M. da G. Recurrence of nonsyndromic odontogenic keratocyst after marsupialization and delayed enucleation vs. enucleation alone: a systematic review and meta-analysis. Oral Maxillofac Surg. 2019 Mar 6; 23 (1): 1-11 .
46. Cunha J.F., Gomes C.C., De Mesquita R.A., Andrade Goulart E.M., De Castro W.H., Gomez R.S. Clinicopathologic features associated with recurrence of the odontogenic keratocyst: A cohort retrospective analysis. Oral Surg Oral Med Oral Pathol Oral Radiol. 2016 Jun 1; 121 (6): 629-35.
47. Donnelly L.A., Simmons T.H., Blitstein B.J., Pham M.H., Saha P.T., Phillips C., et al. Modified Carnoy's Compared to Carnoy's Solution Is Equally Effective in Preventing Recurrence of Odontogenic Keratocysts. J Oral Maxillofac Surg. 2021 Sep 1; 79 (9): 1874-81.

48. Motaleb L., Zakai D., Stocker J. Fourteen-year study of the management of the odontogenic keratocyst. Are adjunctive therapies all they are cut out to be? Br J Oral Maxillofac Surg. 2022 Feb 1; 60 (2): 105-12.
49. Schmidt B.L., Pogrel M.A. The use of enucleation and liquid nitrogen cryotherapy in the management of odontogenic keratocysts. J Oral Maxillofac Surg [Internet]. 2001 [cited 2022 Oct 13]; 59 (7): 720-5. Available from: https://pubmed.ncbi.nlm.nih.gov/11429726/
50. Ribeiro-Júnior O., Borba A.M., Alves C.A.F., de GOuveia M.M., Deboni M.C.Z., da Graça Naclério-Homem M. Reclassification and treatment of odontogenic keratocysts: A cohort study. Braz Oral Res. 2017; 31 (1): 1-10.