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CLINICAL PAPER

Modified Carnoy's Solution: A Multifaceted Adjunctive Modality for Treatment of Maxillofacial Cysts and Tumors

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Abstract

Introduction Since the debate about carcinogenic potential of Carnoy's solution (CS) in 2000s, many surgeons adopted the use of modified Carnoy's solution (MC). There are many studies comparing the effectiveness of MC with CS for treatment of odontogenic keratocyst (OKC). Seldom are the studies defining versatility of MC in treating maxillofacial cysts and tumors. This case series aims to present diverse use of MC for treatment of maxillofacial cysts and tumors.

Methodology Patients who reported with maxillofacial cysts and tumors from February 2018 to February 2023, and for whom surgical enucleation/resection with chemical cauterization using MC was done, are included in the study. We treated 29 cases of maxillofacial cysts and tumors using MC as a chemical cauterizing agent. Among these, 14 cases were OKC, eight were ameloblastoma, four were odontogenic myxoma, and three were ossifying fibroma.

Results A total of 29 patients (18 males and 11 females) were included in the study. All patients were followed up for 12 months. Of the 29 cases, three cases were of anterior maxilla, out of which lesion recurred in two cases. Other complication reported was of paresthesia in two cases which resolved in 12 months.

Conclusion Various treatment modalities are available to treat maxillofacial cysts and tumors but use of MC is an effective modality which reduces risk of recurrence. However, as it poses a risk of damage to surrounding neurovascular structures, caution is needed.

Keywords Modified Carnoy's solution · Carnoy's solution · Maxillofacial cysts · Odontogenic keratocyst · Ameloblastoma

Introduction

Introduced in the late nineteenth century, Carnoy's solution (CS) has been a staple for fixing tissues and enhancing nuclear clarity in nematodes [1]. It has a long-standing history as an effective fixative used in histopathology and cytology studies. First documented in 1931 by Cutler and Zollinger [2], this agent was used as a sclerosant for treating cysts and fistulae, who noted its moderate penetration, rapid fixation, and excellent hemostatic properties. Decades later, in 1981, Voorsmit delineated its exact composition as ethanol, chloroform, and glacial acetic acid in a 6:3:1 ratio, with

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ferric chloride added [3]. By inducing shrinkage, absolute alcohol hardens the tissue. Glacial acetic acid counteracts this by swelling the tissue, thus preventing it from becoming overly hard. Chloroform boosts the speed of fixation, and ferric chloride assists in removing moisture from the tissue [4]. Utilized in the management of different cysts and tumors in the maxillofacial region, this agent is used for chemical cauterization following lesion enucleation. Its effectiveness in treating odontogenic keratocysts (OKCs) has been well-documented. Rajesh Kumar et al. [5] have concluded in their research that Carnoy's solution is a viable and conservative management strategy for aggressive yet benign lesions of maxillofacial region such as OKCs, ameloblastoma, and ossifying fibroma (OF).

The inclusion of chloroform, deemed 'reasonably anticipated to be a human carcinogen' by animal studies, led the FDA to ban CS in 2013. Surgeons responded by using modified Carnoy's solution (MC), which lacks chloroform [6]. A recent systematic review indicates that MC is comparable to CS in terms of safety and efficacy for treating OKCs [7]. There are many studies comparing the effectiveness of MC with CS for treatment of OKC. Seldom are the studies defining versatility of MC in treating maxillofacial cysts and tumors. This case series aims to present diverse use of MC for treatment of maxillofacial cysts and tumors.

Methodology

Patients who reported with maxillofacial cysts and tumors from February 2018 to February 2023, and for whom surgical enucleation/resection with chemical cauterization using MC was done, are included in the study. The protocol was approved by Institutional Review Board, and written consent was obtained from patients included in the study. We treated 29 cases of maxillofacial cysts and tumors using MC as a chemical cauterizing agent. Among these, 14 cases were OKC, eight were ameloblastoma, four were odontogenic myxoma (OM), and three were ossifying fibroma (Table 1).

In 14 cases of OKC, two cases were of anterior maxilla and 12 cases of mandible (Table 2).

Table 1 Type of maxillofacial cyst/tumor and gender-wise distribution

Lesion	Total No. of Cases	Male	Female
OKC	14	8	6
Ameloblastoma	8	5	3
Odontogenic Myxoma	4	3	1
Ossifying fibroma	3	2	1

In eight patients with ameloblastoma, the site ranged from posterior mandible to anterior mandible on both sides (Table 2). They were treated with resection without continuity defect, followed by application of MC and followed by reconstruction wherever necessary.

In four cases of OM of which three cases (males) were in the region between lower molar and premolar region, while in one case (female), it was in the anterior mandible (Table 2). They were treated with enucleation and curettage followed by application of MC.

Three cases of OF were treated with enucleation and application of MC (Table 2). A 35-year-old female patient, with diagnosis of cemento-ossifying fibroma in the left posterior mandible was treated 2 years back with enucleation without chemical cauterization with MC. She had reported with recurrence within 8 months and was re-operated with enucleation with chemical cauterization using MC.

Surgery was planned after confirming the diagnosis with incisional biopsy. CBCT was done to determine the extent of the lesion. All the surgeries were done by same operator. The patients were draped under general anesthesia, and nasal intubation was done. Intraoral/extraoral incisions were given to approach the mandible. Enucleation was done along with curettage and chemical cauterization using MC for lesions on the mandible. The sample collected was sent for histopathological examination. For maxillary lesions, intraoral vestibular approach was used. The affected mobile teeth were removed in all cases. Marginal resection was done in cases of ameloblastoma. Reconstruction with fibula graft was done when necessary. Closure was done using 3–0 vicryl sutures and 3–0 ethilon sutures. After discharge, the patients were recalled after one week for postoperative OPG. Medications consisted of antibiotics, steroids, and analgesics for every patient. Postoperatively, patients were reviewed within the first week, third week, and quarterly in one year period. The follow-up period ranged from 12–60 months.

Results

A total of 29 patients (18 males and 11 females) were included in the study. All patients were followed up for minimum 12 months.

Of the 29 cases, two cases were of anterior maxilla in which recurrence was seen at 8 months postoperatively. They were then treated with 5-fluorouracil (5FU). The sample was collected of every case and sent for histopathological examination and the final diagnosis of each case is mentioned below (Table 2). There was no recurrence till the last follow-up in other 27 cases. Other complication reported was of transient mandibular paresthesia in almost all cases except for a few in which the lesion size was small. All the patients recovered within 4–6 weeks

Table 2 Region involved by maxillofacial cyst/tumor

Lesion	Gender	Age	Region
OKC	M	22	Anterior maxilla
	M	24	Posterior right mandible
	M	35	Posterior right mandible
	F	40	Anterior mandible
	M	30	Posterior left mandible
	F	21	Anterior maxilla
	F	37	Posterior left mandible
	M	26	Posterior left mandible
	F	39	Posterior left mandible
	M	42	Posterior right mandible
	F	15	Posterior left mandible
	F	36	Posterior left mandible
	M	13	Anterior mandible
	M	32	Posterior left mandible
Ameloblastoma	M	30	Posterior right mandible
	M	51	Posterior right mandible including ramus
	F	39	Posterior left mandible
	M	45	Posterior right mandible
	F	21	Anterior mandible
	F	36	Anterior mandible
	M	46	Posterior right mandible
	M	48	Posterior right mandible
Odontogenic myxoma	M	33	Left mandibular molar and premolar region
	M	45	Left mandibular molar and premolar region
	M	52	Right mandibular molar and premolar region
Ossifying fibroma	F	35	Posterior left mandible
	M	59	Anterior mandible
	M	50	Posterior left mandible

postoperatively except five cases which resolved within 6 months and two cases which resolved within 12 months. The one case which was re-operated with the application of MC did not show recurrence till the last follow-up (Figs. 1a, b, 2a, b, c). In one case, there was pathological fracture, which was managed by reconstruction plate. And one case was managed by reconstruction with fibula graft (Figs. 3, 4, 5, 6).

Discussion

Voorsmit established a clinical protocol for applying Carnoy's solution over a period of 5 min on the bony defect, which promoted necrosis of approximately 1.5 mm in depth [3]. After 5-min application, the penetration for bone is 1.54 mm, nerve 0.15 mm, and mucosa to a depth of 0.51 mm. Initially, the Carnoy's solution consisted of

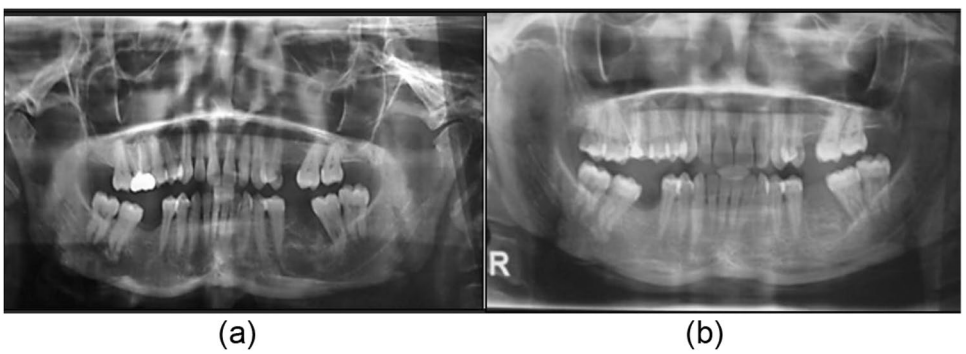

Fig. 1 **a** Ossifying fibroma of left mandible. **b** Enucleation and curettage done

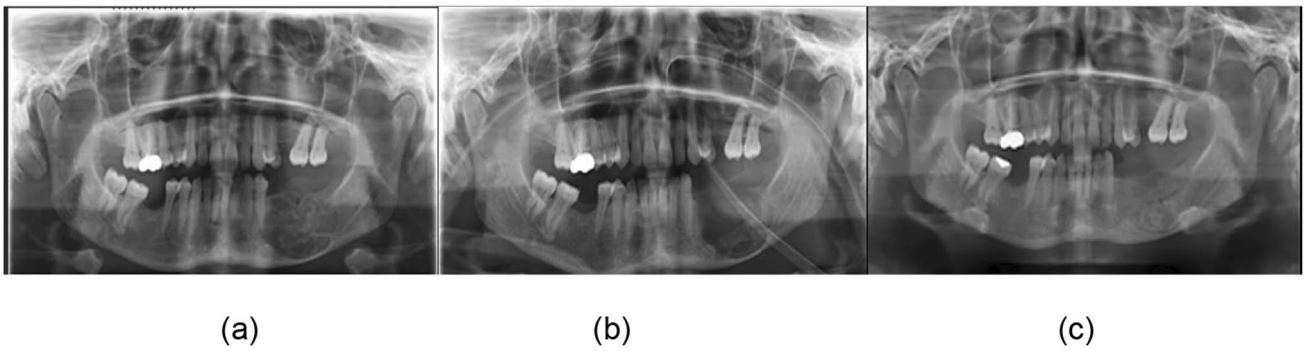

Fig. 2 **a** Recurrence after 8 months. **b** Immediate postop MC. **c** 12-month follow-up

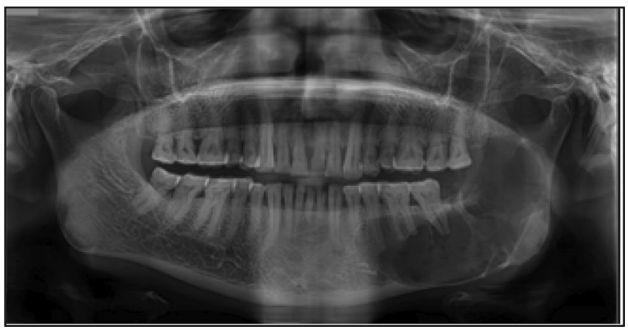

Fig. 3 Ameloblastoma of left mandible

- 6 ml of 95% ethanol
- 3 ml of glacial acetic acid and
- 1 g of ferric chloride [1]

Subsequently, there were two important changes in its formulation:

(1) Presence of 6 ml of absolute alcohol instead of ethanol and
(2) Addition of chloroform of 3 ml [2]

The inclusion of chloroform, deemed 'reasonably anticipated to be a human carcinogen' by animal studies, led the FDA to ban CS in 2013, which in turn led the surgeons to use MC as an adjunct instead of CS.

A study conducted to compare MC and CS in the management of OKC showed that the application of MC has an efficiency comparable to that of CS for lowering the recurrence rate [8]. Similar results were obtained in a retrospective cohort study by Donnelly LA et al. [6].

Stoelinga and Bronkhorst, in 1988, were the pioneers in suggesting the use of CS to mitigate recurrence risks following routine conservative surgical procedures for unicystic ameloblastoma [9]. Since then, numerous case reports have been published showing efficacy of CS as an adjunctive modality. A study of ten years' experience of using CS as an adjunct for treatment of ameloblastoma, irrespective of the

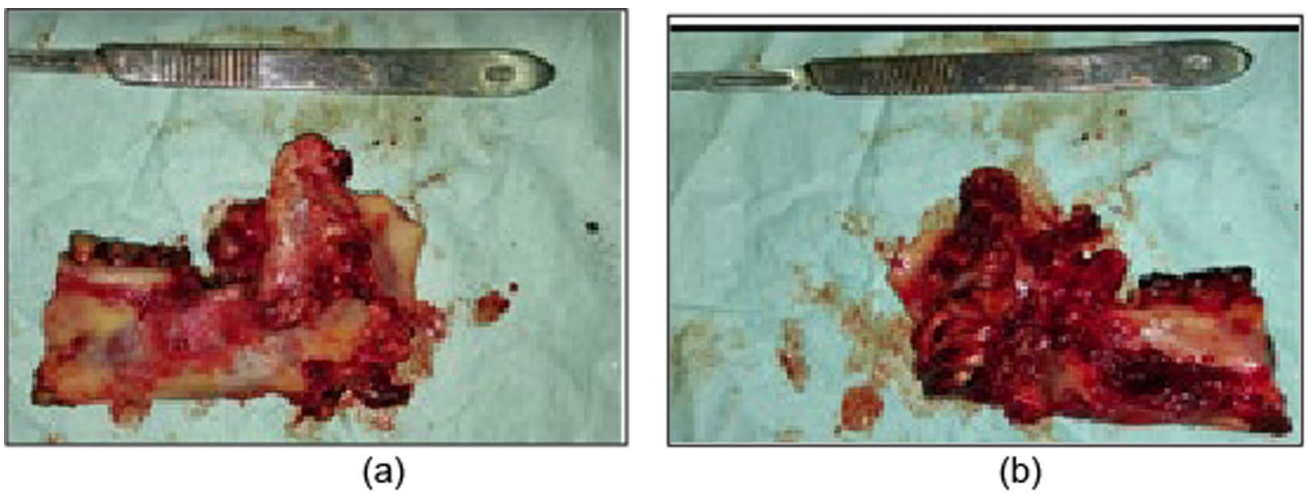

Fig. 4 **a** Excised mandible (buccal view). **b** Excised mandible (lingual view)

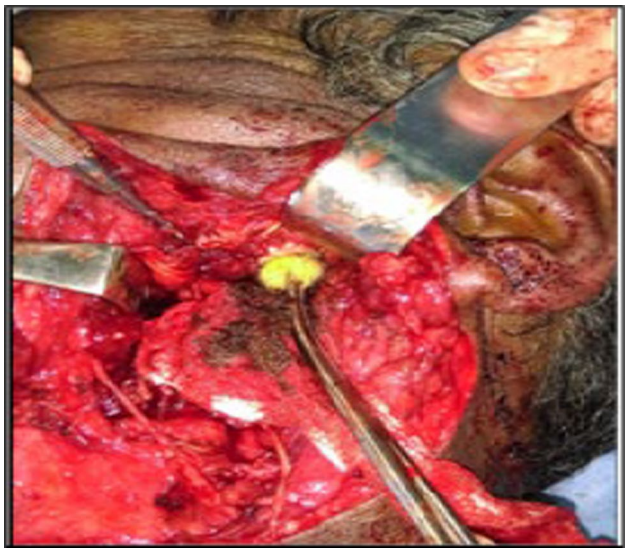

Fig. 5 Application of MC in residual defect

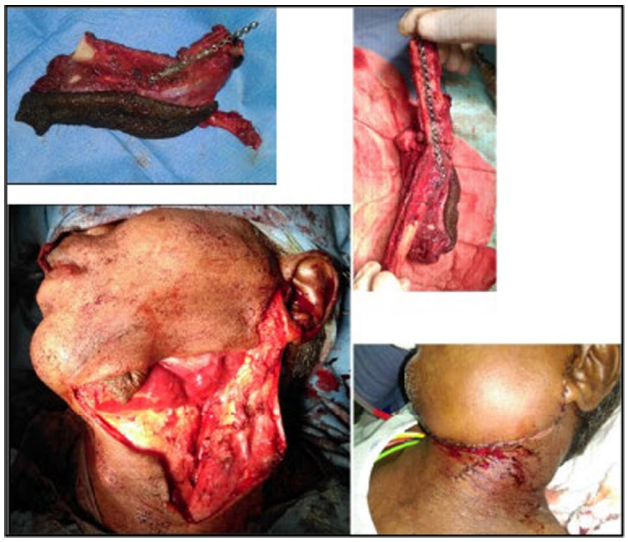

Fig. 6 Reconstruction of the defect by fibula graft

histological type, showed benefits of chemical cauterization of the ameloblastoma cystic cavity [10]. A systematic review says that recurrence rates of OKC and ameloblastomas have gone down from 60–80% to 6.6–11.5% by application of CS or its modifications [11].

The purpose of this study was to identify the diverse use of MC as an adjunctive for treatment of benign but aggressive maxillofacial cysts and tumors such as OKC, ameloblastoma, OM, and OF. The use of CS as an adjunctive to treat OKC has been well-established by several studies. Rajesh Kumar et al. [5] gave positive results when CS was used as an adjunctive modality to treat OKC, unicystic ameloblastoma, and juvenile ossifying fibroma. B. Lal et al. [12], in their systematic review, found 11 different types of maxillofacial lesions in which CS was used as an adjunctive modality, where recurrence was reported only in ameloblastoma cases. Similarly, our study also shows MC being effective for various benign aggressive lesions of maxillofacial region including ameloblastoma. Contrary to this, a systematic review evaluating the safety and efficacy of CS, MC, and 5FU in treating OKC found that patients treated with MC experienced recurrence rates between 19 and 67%, while those treated with CS and 5FU had no recurrences. However, the author concludes that with the ban of CS, both MC and 5FU are suitable treatment options [7].

The study revealed a 6.8% recurrence rate, exclusively in anterior maxillary cases that were treated with MC. These cases were subsequently treated with 5FU without encountering any complications. As mentioned by Ledderhof NJ et al. [13], 5FU is a novel targeted adjunctive therapy for management of OKC. A systematic review by Singh AK et al. [14] also states that 5FU has the potential to become an alternative to MC. According to the study by Akhter Lone et al. [15], similar findings have highlighted the maxilla's proximity to the orbital contents and major vessels. We believe these anatomical factors contributed to the improper application of MC in maxillary cases, resulting in lesion recurrence. We further propose that 5FU can be safely used in maxillary lesions due to its lower postoperative morbidity and targeted therapeutic action, unlike MC, which penetrates surrounding structures and causes necrosis.

With the advantage of use of MC as an adjunct, also comes its drawback that it can damage the normal tissues and cause sensory disturbances. Out of the lot, a few patients (24.1%) experienced persistent paresthesia which was recovered shortly after surgery. Similar findings were reported in a study where CS was used in OKC and ameloblastoma cases [16]. Contrary to this, a systematic review by Winters R et al. [7] shows that patients treated with CS and MC had complaints of permanent paresthesia when compared to 5FU.

Critical exposure time for CS when applied over the inferior alveolar nerve (IAN) of rabbits has been given as 3 min, beyond which the neural tissue disintegrates [17]. Recently, an experimental study was conducted by Karthik R et al. [18] on Wistar rats to compare the depth of penetration and amount of bone necrosis of CS vs MC, and it was concluded that the exposure time for MC should be 10 min to get the similar results as CS. However, in our patients, we have kept the exposure time to 5 min.

Conclusion

This case series shows that MC can be used as an effective adjunctive modality for treatment of aggressive but benign maxillofacial cysts and tumors, with low recurrence rate and

less postoperative complications. Further, 5FU in the form of paste has been deemed more effective for treating OKC in maxilla due to its quick procedure time, widespread availability, ease of use, lower morbidity rates, cost-efficiency, and minimal or no recurrence, which reduces the chances of needing a subsequent surgery.

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Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. The authors have no financial or proprietary interests in any material discussed in this article.

References

1. Hellstein J, Hopkins T, Morgan T (2007) The history and mystery of carnoy solution: an assessment of the need for chloroform. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 103:e24
2. Cutler EC, Zollinger R (1933) Sclerosing solution in the treatment of cysts and fistulae. Am J Surg 19:411–418. https://doi.org/10.1016/S0002-9610(33)90796-5
3. Voorsmit RA, Stoelinga PJ, van Haelst UJ (1981) The management of keratocysts. J Maxillofac Surg 9(4):228–236. https://doi.org/10.1016/s0301-0503(81)80049-5
4. Matijević S, Damjanović Z, Lazić Z, Gardasević M, Radenović-Djurić D (2012) Peripheral ostectomy with the use of Carnoy's solution as a rational surgical approach to odontogenic keratocyst: a case report with a 5-year follow-up. Vojnosanit Pregl 69(12):1101–1105
5. Rajeshkumar BP, Rai KK, Geetha NT, Shivakumar HR, Upasi AP (2013) Carnoy's in aggressive lesions: our experience. J Maxillofac Oral Surg 12(1):42–47. https://doi.org/10.1007/s12663-012-0371-9
6. Donnelly LA, Simmons TH, Blitstein BJ, Pham MH, Saha PT, Phillips C, White RP, Blakey GH (2021) Modified carnoy's compared to carnoy's solution is equally effective in preventing recurrence of odontogenic keratocysts. J Oral Maxillofac Surg 79(9):1874–1881. https://doi.org/10.1016/j.joms.2021.03.010
7. Winters R, Garip M, Meeus J, Coropciuc R, Politis C (2023) Safety and efficacy of adjunctive therapy in the treatment of odontogenic keratocyst: a systematic review. Br J Oral Maxillofac Surg 61(5):331–336. https://doi.org/10.1016/j.bjoms.2023.04.006
8. Janas-Naze A, Zhang W, Szuta M (2023) Modified carnoy's versus carnoy's solution in the management of odontogenic keratocysts-a single center experience. J Clin Med 12(3):1133. https://doi.org/10.3390/jcm12031133
9. Stoelinga PJ, Bronkhorst FB (1988) The incidence, multiple presentation and recurrence of aggressive cysts of the jaws. J Craniomaxillofac Surg 16(4):184–195. https://doi.org/10.1016/s1010-5182(88)80044-1
10. Haq J, Siddiqui S, McGurk M (2015) The use of Carnoy's solution following enucleation of ameloblastoma: ten year's experience. Br J Oral Maxillofac Surg 53(10):e55. https://doi.org/10.1016/j.bjoms.2015.08.057
11. Lebedev VV, Butsan SB (2019) The use of carnoy's solution and its modifications for reducing the number of recurrences after surgical removal of keratocystic odontogenic tumors and ameloblastomas: a systematic review. Moscow Univ Biol Sci Bull 74:108–116. https://doi.org/10.3103/S0096392519020068
12. Lal B, Kumar RD, Alagarsamy R, Shanmuga Sundaram D, Bhutia O, Roychoudhury A (2021) Role of Carnoy's solution as treatment adjunct in jaw lesions other than odontogenic keratocyst: a systematic review. Br J Oral Maxillofac Surg 59(7):729–741. https://doi.org/10.1016/j.bjoms.2020.12.019
13. Ledderhof NJ, Caminiti MF, Bradley G, Lam DK (2017) Topical 5-Fluorouracil is a Novel Targeted Therapy for the Keratocystic Odontogenic Tumor. J Oral Maxillofac Surg 75(3):514–524. https://doi.org/10.1016/j.joms.2016.09.039
14. Singh AK, Khanal N, Chaulagain R, Bhujel N, Singh RP (2022) How effective is 5- Fluorouracil as an adjuvant in the management of odontogenic keratocyst? A systematic review and meta-analysis. Br J Oral Maxillofac Surg 60(6):746–754. https://doi.org/10.1016/j.bjoms.2022.02.001
15. Akhter Lone P, Ahmed Wani N, Ahmed Janbaz Z, Bibi M, Kour A (2020) Topical 5- fluorouracil application in management of odontogenic keratocysts. J Oral Biol Craniofac Res 10(4):404–406. https://doi.org/10.1016/j.jobcr.2020.07.008
16. Jo HJ, Kim HY, Kang DC et al (2020) A clinical study of inferior alveolar nerve damage caused by Carnoy's solution used as a complementary therapeutic agent in a cystic lesion. Maxillofac Plast Reconstr Surg 42:16. https://doi.org/10.1186/s40902-020-00257-4
17. Frerich B, Cornelius CP, Wiethölter H (1994) Critical time of exposure of the rabbit inferior alveolar nerve to Carnoy's solution. J Oral Maxillofac Surg 52(6):599–606. https://doi.org/10.1016/0278-2391(94)90098-1
18. Karthik R, Lakshmi Rathan AC, Sapna S, Cynthia S, Sathyakumar M, Magesh KT (2023) Is modified Carnoy's solution as effective as Carnoy's solution in terms of amount of bone necrosis and depth of penetration? Br J Oral Maxillofac Surg 61(3):233–239. https://doi.org/10.1016/j.bjoms.2023.02.004