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Systematic Review

Lead Airgun Projectiles Inside the Maxillary Sinuses—Therapeutic Approaches through the Years: A Systematic Review of Case Reports

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Abstract: Background: Shots from commonly available non-gunpowder weapons are a significant cause of facial injuries, especially in pediatric patients. A consequence of such trauma may be the placement of a projectile within the maxillary sinus, which is a therapeutic need with no guidelines for foreign body removal. The purpose of this paper is to discuss the etiology, epidemiology, diagnosis, treatment and prognosis of such cases. Materials and methods: Any cases describing the presence of airgun pellets within the maxillary sinus were included. Animal patients and non-English cases were excluded. The final search using the PubMed, BASE and Google Scholar engines was made on 13 November 2021. The JBI Critical Appraisal Checklist for Case Reports was used to assess the risk of bias. The collected data are presented in tabular form and were subjected to a comparative assessment. Results: In total, reports of seven cases of lead airgun projectiles in the maxillary sinuses were identified, qualified and analyzed. There were no cases of lead intoxication. The bullets were removed by open surgery in the form of antrostomy of the maxillary sinus or with the use of an endoscope. In none of the described cases were complications observed during surgery or postoperative observation. Discussion: This systematic review was based on case reports that differed significantly in quality. The location of the lead foreign body within the maxillary sinuses may be considered favorable over other craniofacial gunshots. The risk of lead intoxication does exist, but such a location of the bullets does not favor it. The removal of projectiles from the maxillary sinuses appears to be easily achievable and does not predispose one to complications.

Keywords: penetrating head injuries; gunshot wounds; foreign bodies; lead poisoning; maxillary sinus

1. Introduction

1.1. Rationale

In the group of children over 10 years of age, facial injuries most often occur during sports or as a result of a gunshot with non-powder weapons [1,2]. On the basis of the calculations of Jones et al., it may be assumed that more than 13,000 gunshots of children with NPWs occur annually in the United States alone [1]. Almost half of the NPWs shots in pediatric patients leave a projectile within tissues [1]. The barrier of only the cheek skin

and a thin anterior wall of the maxillary sinus makes it likely that the projectile will enter the area of the maxillary sinus in the event of a shot in this area.

A non-powder weapon (NPW) is one that uses the force of compressed air or other gas, springs, or electricity to fire a projectile. This category includes: (1) airguns (AGs); (2) airsoft guns; (3) paintball guns [1]. Weapons of these types are available without authorization in most countries. Depending on local regulations, this availability may be limited due to the power of the weapon, which, however, does not exclude illegal modifications aimed at increasing the power of the shot. While airsoft and paintball guns were developed with the intention of not injuring individuals, AGs pose a real threat to the tissues and even the general health and life of someone who has been shot [1–3]. AGs come in the form of both pistols and rifles and fire spherical BB bullets or diabolo-shaped pellets [1].

Lead BBs and pellets, apart from the ability to pierce the skin and mechanically damage tissues, are also a potential source of lead poisoning [3]. In 2021, Holmgren et al. developed the latest guidelines for penetrating midface trauma [4]. The paper by Holmgren et al. defines the next stages of the procedure from admitting the patient to the decision on surgical removal of the foreign body, if possible [4]. However, the surgical removal of the body from the midface is not intuitive and also requires evidence-based guidelines. The maxillary sinus is the craniofacial cavity, unique in that it is of interest to otorhinolaryngologists and maxillofacial surgeons. The location and the large volume of the maxillary sinus can therefore cause therapeutic dilemmas, in particular with regard to proper surgical access.

1.2. Objectives

In this research, an attempt was made to collect all contemporary cases of lead bullets from non-powder weapons within the maxillary sinuses described in the literature (in English). The purpose of obtaining, compiling and analyzing these data was to determine the etiology, epidemiology, diagnostic and therapeutic possibilities as well as give a prognosis of these cases.

2. Materials and Methods

2.1. Registration and Protocol

This systematic review was approved at the design stage by the Center for Reviews and Dissemination (University of York, York, UK) and registered in the PROSPERO database International prospective register of systematic reviews under CRD42021278385. The systematic review was prepared in accordance with the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyzes (PRISMA) [5]. The PRISMA 2020 Checklist and Abstracts Checklist are in Supplementary Files S1 and S2, respectively. The protocol of this systematic review has not been published so far and is presented in the following chapters of this article.

2.2. Eligibility Criteria

The systematic review method was used to achieve the above-mentioned objectives. The eligibility of the articles was determined using the PICOTS framework [6]. The individual letters of the acronym stand for: (1) patient; (2) (surgical) intervention; (3) comparison (to the control case or cases); (4) results (of the intervention); (5) timeframe; (6) study design [6]. The eligibility criteria are detailed in Table 1. In order to avoid historical and, therefore, clinically useless diagnostic and therapeutic methods, the time frame of this review was limited to the last quarter of a century.

Table 1. Eligibility criteria for articles constituting material for the systematic review. PICOTS framework was adapted [6].

	Inclusion Criteria	Exclusion Criteria
Patient	Confirmed presence of a lead projectile from NPW within the maxillary sinus	Animal patients
Intervention	Removal of the projectile from the maxillary sinus	Any type of maxilla resection
Comparison	A control case or cases are not required	-
Outcomes	No macroscopically detectable foreign bodies within the maxillary sinuses	-
Timeframe	Papers published since 1995	-
Study design	Any primary research	Papers published in languages other than English

2.3. Information Sources

Two engines, i.e., Pubmed and Bielefeld Academic Search Engine (BASE), were used to search for articles for the purpose of this systematic review [7,8]. The first of these searches, of the PubMed database, found over 32 million records [7]. The BASE engine found over 240 million records from over 8000 content providers [8]. These engines were chosen for their general availability and independence from scientific journal publishers [7,8]. Additionally, the Google engine was used to search the Google Scholar database as a potential source of gray literature [9]. Final searches using all engines were made on 13 November 2021.

2.4. Search Strategies

On the basis of the eligibility criteria, keyword combinations constituting search queries were developed. Due to the popular use of the term "pellets" in relation to bone augmentation materials, additional keywords "augmentation" and "sinus lift" were used to exclude articles related to sinus lift procedures. The individual search strategies for the PubMed, BASE and Google Scholar engines are presented in Table 2.

Table 2. Strategies to search for articles that served as materials for the systematic review.

	Search Strategy
PubMed	(lead OR Pb OR metal OR metallic) AND (BB OR pellet OR projectile OR bullet OR shot OR buckshot OR birdshot) AND maxillary AND (sinus OR antrum) NOT augmentation NOT "sinus lift"
BASE	(lead Pb metal metallic) AND (BB pellet projectile bullet shot buckshot birdshot) AND maxillary AND (sinus antrum) -augmentation -"sinus lift"
Google Scholar	lead OR Pb OR metal OR metallic BB OR pellet OR projectile OR bullet OR shot OR buckshot OR birdshot maxillary sinus OR antrum -augmentation -"sinus lift"

2.5. Selection Process

All records found on to the PubMed and BASE engines were included in the automated selection process [7,8]. This process was carried out independently by two researchers (M.C. and Z.N.) using the Rayyan application (Rayyan Systems Inc. Cambridge, MA, USA) [10]. Articles from the Google Scholar database were selected by two researchers (M.C. and Z.N.) manually [9]. Due to the specificity of the Google search engine, based on relevance and not exact matching, the first 50 records were assessed in this way [9]. For each type of search, articles were initially selected based on their titles and abstracts. The convergence of assessments was expressed by the Cohen's kappa coefficient. In the next stage, the assessment was made on the basis of the full contents of the articles. The rejection of articles at each stage was made on the basis of non-compliance with the previously

adopted eligibility criteria. These criteria were applied sequentially and in the event of non-compliance with the previous one, the next ones were not checked. In the event of inconsistency in the assessments, the article was moved to the next stage. The selection process was presented graphically using the PRISMA flow diagram [5].

2.6. Data Collection Process

The data contained in the articles were extracted independently by two authors (M.C. and P.Z.) and compiled in the form of a table. In case of inconsistency of the extracted data, the authors discussed the inconsistency and made a joint decision. In disputes, a specific author (M.C.) had the decisive voice.

2.7. Data Items

The following data were extracted from the articles: (1) year of publication of the article; (2) the name of the first author of the article; (3) the patient's age at the time of surgery; (4) time from injury to surgery; (5) symptoms on admission for surgery; (6) surgical access; (7) use of an endoscope; (8) the course of the postoperative period. All data meeting the specified criteria were extracted. In the absence of data, this fact was clearly indicated.

2.8. Study Risk of Bias Assessment

Due to the classification of case reports only, the bias risk assessment was performed using the JBI Critical Appraisal Checklist for Case Reports [11]. This evaluation was made independently by two authors (M.C. and Z.N.). In case of discrepancy in assessments, the issue was discussed, and in the absence of consensus, the final decision rested with one of the authors (M.C.).

2.9. Synthesis Methods

The data were synthesized in the form of a tabular summary (P.Z. and M.C.). Due to the modest amount of quantified data, no statistical analysis was performed in this systematic review. The numerical results were presented in the form of diagrams and the non-numeric data were discussed.

3. Results

3.1. Studies Selection

The course of article selection in the form of a PRISMA flow diagram is shown in Figure 1 [5]. In total, 27 unique records found in the PubMed and BASE studies, along with the decisions for qualification at the screening stage, are included in Supplementary S3 (agreement: 96.3%; Cohen's k = 0.78). Supplementary S4 contains a list of articles found using the Google engine along with the consistent decisions about their qualification at the screening stage.

3.2. Included Studies

The articles describing single and multiple cases of NPWs projectiles within the maxillary sinuses were qualified for the systematic review. The list of these articles is presented in Table 3.

Table 3. Articles included in the systematic review.

Year of Publication	First Author	Title	Number of Cases
1995	O'Connell [12]	Air gun pellets in the sinuses.	2
2004	Mahajan [13]	Accidental lodgment of an air gun pellet in the maxillary sinus of a 6-year old girl: a case report.	1
2004	Brinson [14]	Endoscopic management of retained airgun projectiles in the paranasal sinuses.	1
2008	Qiam ud Din [15]	Air Gun Pellet in Maxillary Sinus.	2
2010	Kühnel [16]	Air gun pellet remaining in the maxillary sinus for 50 years: a relevant risk factor for the patient?	1

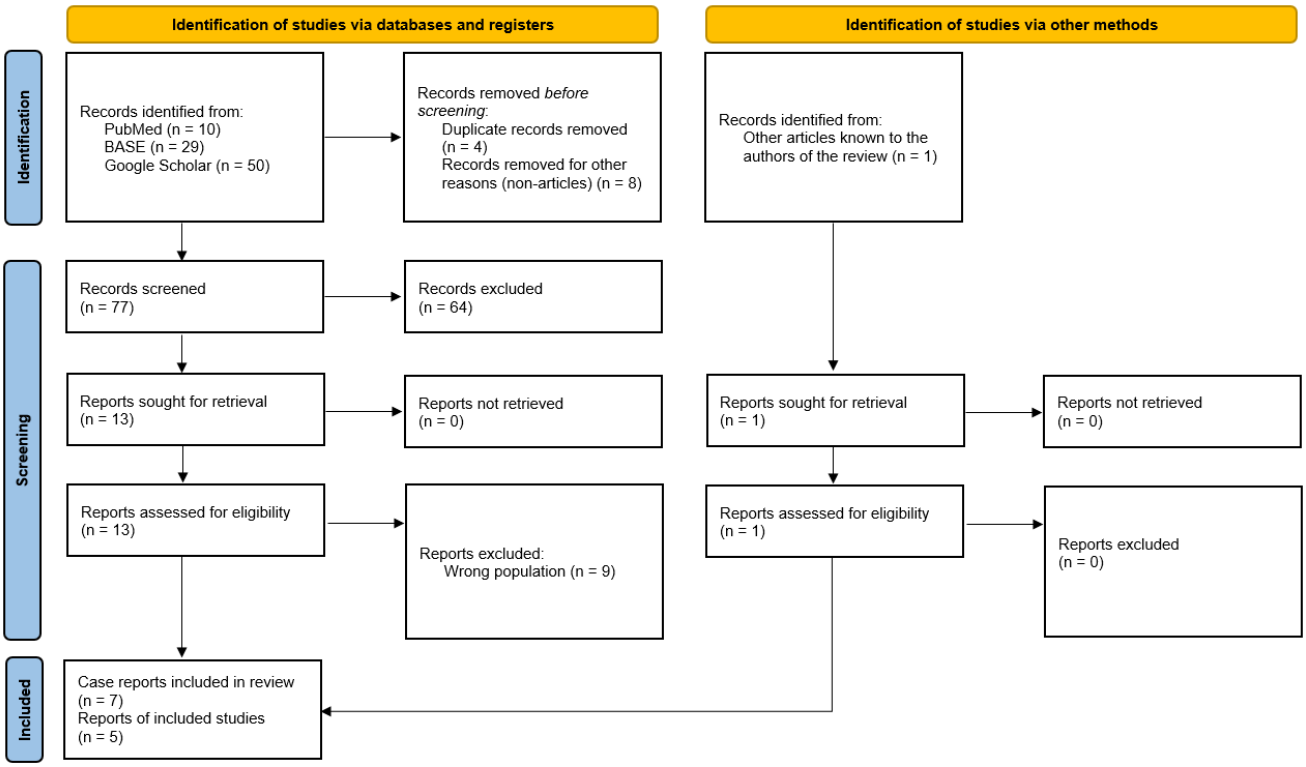

Figure 1. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources [5].

3.3. Risk of Bias

The results of the bias risk assessment are presented in Table 4. Due to the identification of only a handful of articles meeting the eligibility criteria, it was decided to include each item that met at least half of the requirements of the JBI Critical Appraisal Checklist for Case Reports [11].

3.4. Comparison

Table 5 compares the lead airgun projectiles inside the maxillary sinuses identified in the literature and left after the bias risk assessment.

Table 4. Bias risk assessment. Possible answers to the questions: yes/no/unclear/not applicable. Possible overall appraisal: include/exclude/seek further info. JBI Critical Appraisal Checklist for Case Reports was used [11].

First Author	Were the Patient's Demographic Characteristics Clearly Described?	Was the Patient's History Clearly Described and Presented as a Timeline?	Was the Current Clinical Condition of the Patient on Presentation Clearly Described?	Were Diagnostic Tests or Assessment Methods and the Results Clearly Described?	Was the Intervention(s) or Treatment Procedure(s) clearly Described?	Was the Post-Intervention Clinical Condition Clearly Described?	Were Adverse Events (Harms) or Unanticipated Events Identified and Described?	Does the Case Report Provide Takeaway Lessons?	Overall Appraisal
O'Connell [12]	Yes	No	No	Yes	Yes	No	Not applicable	Yes	Include
Mahajan [13]	Yes	Yes	Yes	Yes	Not applicable	Not applicable	Not applicable	Yes	Include
Brinson [14]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Include
Qiam ud Din [15]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Include
Kühnel [16]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Include

Table 5. Case comparison.

First Author	Age at the Admission and Gender of the Patient	External Symptoms	Inflammation of the Sinus Mucosa	Lead Intoxication Symptoms	Time from Injury to Surgery	Diagnostic Methods	Surgical Approach	Recovery
O'Connell [12]	14-year-old boy	Unknown	Unknown	Unknown	Unknown	computed tomography (CT) scan, sinus X-rays	Caldwell-Luc approach	Uneventful
	16year-old boy	Cheek skin injury Slight swelling	Unknown	Unknown	Unknown	sinus X-rays	Caldwell-Luc approach	Unknown
Mahajan [13]	6-year-old girl	Small skin scar on the cheek	Yes	No	1 week	sinus X-rays	Unknown	Unknown
Brinson [14]	8-year-old girl	Cheek skin injury Slight swelling Hypoesthesia of the infraorbital region	Unknown	No	2 weeks	CT scan	Endoscopic antrostomy	Uneventful The hypoesthesia resolved within 2 weeks
Qiam ud Din [15]	13-year-old girl	Scar on the cheek Slight tenderness	Unknown	Unknown	Immediate	OPG X-ray	Caldwell-Luc approach	Uneventful
	30-year-old woman	Scar on the cheek Oroantral fistula	Unknown	Unknown	Immediate	OPG X-ray	Caldwell-Luc approach	Uneventful
Kühnel [16]	62-year-old man	None	Unknown	Unknown	50 years	CT scan, sinus X-rays, laboratory blood examination	Endoscopic antrostomy	Uneventful

3.5. Age and Gender

In all but one case, a lead NPW bullet ended up in the maxillary sinus as a result ofa gunshot. The only adult case was described by Qiam ud Din et al. and concerned a 30-year-old woman [15]. The patient described by Kühnel et al. was treated a 62-year-old adult but was shot 50 years earlier, at the age of 12 [16]. In the material studied, the gunshots occurred almost equally in both sexes.

3.6. External Symptoms

The external symptoms of the gunshot were a wound or a scar as a consequence. Swelling and tenderness were also observed in unhealed skin wounds. One case of infraorbital hypoesthesia was reported, most likely resulting from direct injury or indirect compression of the infraorbital nerve [14]. In only one case was an oroantral fistula observed as a result of a gunshot [15]. Interestingly, it was the only case of an adult in the studied material [15].

3.7. Inflammation of the Sinus Mucosa

Most of the authors of the articles describing the cases of the gunshots in question did not provide information on any noticeable inflammation of the mucosa of the maxillary sinus. In only one case did the authors note symptoms of chronic sinusitis [13].

3.8. Time from Injury to Surgery

One case describes the survival of a bullet in the maxillary sinus for 50 years, which gave rise to testing for lead poisoning [16]. In the remaining cases, the removal of the foreign body was performed up to 2 weeks after the incident or the period between the shot and surgery was not specified.

3.9. Diagnostic Methods

In all discussed cases, the routine physical examination was followed by radiological assessment. Most authors describe the use of sinus X-rays: occipitomental, occipitofrontal and/or lateral views. Qiam ud Din et al. [15] based their diagnostic and therapeutic approach on OPG X-rays in both presented cases. Three out of seven of the analyzed cases were assessed with the aid of CT scans.

3.10. Surgical Approach

Except for one case where the method of projectile removal was not specified, in all other cases the surgical access was through the anterior wall of the maxillary sinus. Four studies used Caldwell-Luc approaches and two made use of a surgical endoscope.

3.11. Recovery

No complications of either surgery or follow-up were reported in any case.

4. Discussion

4.1. Etiology and Epidemiology

According to various studies, 71 to 99% of the NPWs gunshots were unintentional, and about half of them were self-shots [1,17,18]. For the entire group of over 364,000 cases of children gunshots with NPWs, intentional action was reported in 0.54% by Jones et al. [1]. In the NPWs category, BB guns (BBGs) and pellet guns (PGs) accounted for approximately 81% and 16% of pediatric injuries, respectively [1]. According to the same data, almost 40% of gunshots from NPWs targeted the head and neck region [1].

Most of the gunshots from NPWs concerned children and adolescents [1,19]. This is confirmed in our material, where 6 out of 7 cases were gunshots of children. The annual average calculated for the years 1990–2016 is over 8900 BBGs and over 1700 PGs shots of children in the United States of America alone [1]. According to Bratton et al., in the group of 101 children, gunshot injuries were more common among boys (81%), and the average age of the children was 10.9 years [20]. Similar results were reported by Jones et al., i.e., 87.1% of gunshots with NPWs occurred in boys, and the average age of children was 11.8 years [1]. In the cases we analyzed, female gunshots in the ratio 4:3 prevailed. According to another study by Shanon et al., the median age for AG facial injuries was 12, and within their study group, the frequency of head and neck injuries was 51% [21]. The frequency of airgun injuries to the head and neck in the material discussed by Bratton et al. was 49%, and in the material of Jones et al. it was 39.3%. [1,20]. Taking into account the division according to the type of projectile, BBGs and PGs shots targeted the head and neck in 35% and 30% of cases, respectively [1]. Gunshots of the upper limbs in children were as common as those of the head and neck, which in the case of both types of AGs accounted for approximately 30% of cases [1]. Penetrating gunshots with NPWs were exceptionally described in adults, which possibly resulted from the more difficult penetration of mature tissues and a greater tendency to treat injuries of adults on an outpatient basis [15,16].

4.2. Diagnostics

The lead projectile entry wound is often very small and patients may not even be aware that the bullet is stuck in their body [12,14]. Therefore, whenever a shot was fired in the direction of a patient, the bullet must be excluded or located [4]. In order to properly plan and carry out the pellet removal procedure, it is important to precisely localize the foreign body [4,14]. A good visualization of the presence of a shading metal foreign body can be achieved with conventional radiography, cone beam CT and computed tomography [4,22,23]. Nevertheless, in certain cases, computed tomography angiography, interventional radiology and magnetic resonance imaging are used [4]. In most of the cases analyzed in this work, diagnosis was based only on conventional radiography [12,13,15]. Apart from Qiam ud Din et al. [15], who used the orthopantomograms, other authors localized the lead projectiles by conducting the sinus X-rays in two planes [12,13]. However,

computed tomography was also a frequent choice, as three out of seven cases describe its use as well as present appropriate freeze-frames from the examination [12,14,16]. Detailed guidelines for the diagnosis of penetrating midface injuries were presented by Holmgren et al. in a publication from 2021 based on a recent systematic review [4]. According to Goswami et al. and Lubianca Neto et al., a computed tomography scan is an accurate method of locating the pellets within paranasal sinuses, especially when both coronal and axial sections were analyzed [22,24]. Nevertheless, Holmgren et al. state that three-dimensional radiological diagnosis is necessary when the foreign body has penetrated backwards from the maxillary sinuses [4]. In other cases, they recommend the use of conventional radiography in two planes, i.e., posterior–anterior and lateral [4]. It should be emphasized that the guidelines of Holmgren et al. do not apply directly to gunshots and are based on the treatment of injuries caused mainly by objects, some of which were visible outside the tissues, such as knives or utensils [4]. Therefore, the use of three-dimensional imaging whenever possible seems to be justified [22,24]. Even in cases of precise imaging, the assessment of the position of a pellet cannot be considered constant [15]. In the case reported by Qiam ud Din et al., a pellet visualized by means of the CT scan slightly changed its position in comparison to the orthopantomogram performed two weeks earlier [15].

4.3. Treatment

There are known cases of many years of foreign bodies remaining within the maxillary sinuses [16,25,26]. The apparently asymptomatic presence of foreign bodies in the maxillary sinus, however, results in a local inflammatory reaction and the risk of poisoning in the case of toxic materials [16,26–28]. The lead penetration into the blood may depend on the type and location of the pellet and in the case of the maxillary sinus, we may consider the location to be favorable, allowing the separation of the foreign body with the inflamed mucosa [16,27,28]. According to Kikano et al., lead poisoning symptoms are nonspecific, such as anorexia, vomiting, weight loss and renal toxicity [29]. The same authors indicate that chronic body exposure to low doses of lead can cause behavioral changes, low height and weight gain in childhood [29]. However, Kikano et al. also believe that retained pellets are a rare cause of lead poisoning [29]. Among a group of 23 children who were wounded by a gunshot and afterwards examined by these researchers there was no evidence of lead poisoning [29]. As stated in a case report by Kühnel et al., a blood test showed the lead level of 80 mg/L in a patient who was shot 50 years earlier, whereas the reference value is up to 90 mg/L [16]. Kühnel et al. explained the lack of symptoms of lead poisoning in a blood test by the lack of contact of the bullet with the tissue fluid [16]. Thus, it can be assumed that the location of the projectile inside the maxillary sinus is advantageous in terms of avoiding intoxication.

John et al. are of the opinion that lead poisoning from a bullet left in the body is a rare but occurring complication [30]. Other authors believe that metallic foreign bodies such as airgun pellets gradually become surrounded by fibrous tissue and inert to the body [28]. Nevertheless, a pellet left in the body can cause foreign body reaction [27]. On the one hand, there have been reported many serious effects of pellets in the paranasal sinus such as chronic sinusitis, formation of rhinolith and persistent pain [14,15,31]. On the other hand, there are also reports of foreign bodies being present without sequelae [16,24,32,33].

The decision to remove a foreign body can therefore be a topic of discussion. According to the assessment of Yarlagadda et al., based on the analysis of gunshots of the paranasal sinuses and the base of the skull, metal foreign bodies should be removed when surgical treatment is safe and the presence of a foreign body creates a risk of infection [31]. These authors consider the proximity of mucosa to a foreign body to be a risk factor for infection, as is the case in the cases analyzed in this systematic review [31]. The guidelines of Holmgren et al. in each case of a penetrating midface injury suggest a procedure to allow for the surgical removal of the foreign body [4]. In the case of small foreign bodies within the maxillary sinuses, access through the wound or intentional antrotomy carried out in an endoscopic or conventional manner should always be considered [16,31,34].

With such assumptions, it should be considered that metallic foreign bodies from the area of the maxillary sinuses should be removed when the general health of the patients allows it [4,31,34].

In case of a foreign body within the maxillary sinus, a simple method may be the Caldwell-Luc approach, causing minimal complications and a short hospital stay [13]. Nevertheless, according to some authors, most foreign bodies located in the maxillary sinus can be removed by endoscopic antrostomy [14,34,35]. Brinson et al. believe that the antrostomy method is the preferred method of removing only foreign bodies embedded anteriorly or of large dimensions from maxillary sinuses [14]. According to the case reports analyzed in this systematic review, the results of endoscopic and non-endoscopic treatments are equally effective in terms of the absence of intra- and postoperative complications [12–16].

4.4. Prognosis

Injuries caused by airgun shots heal well, the hospital stay is short and the literature does not describe complications after this type of surgery [12,14–16]. However, during the procedure, it is important to remember the possibility of complications such as damage to the infraorbital nerve, intensive bleeding and postoperative complications such as swelling and warming of the face, as well as asymmetry, paraesthesia or oroantral fistula formation [35]. Therefore, we strongly recommend that these types of procedures be performed only by clinicians with extensive experience in maxillofacial surgery.

4.5. Limitations

Due to the lack of other original studies, this systematic review was based on case reports. The case reports included in the review differed significantly in quality, which, in line with the adopted methodology, did not exclude them from the review, but was indicated when assessing the risk of bias.

Therefore, it should be strongly emphasized that the above considerations regarding etiology, epidemiology, diagnosis, treatment and prognosis are based on individual cases of projectiles in the maxillary sinuses and related papers. This limitation is the reason why an attempt was made to define a diagnostic and therapeutic path for the presence of lead airgun projectiles in the maxillary sinuses.

5. Conclusions

Non-powder weapon shots that leave the projectile in the maxillary sinus are rare; they mainly affect children and cause moderate local ailments. To date, no case of lead poisoning due to the presence of a lead NPW bullet in the maxillary sinus has been documented. Computed tomography allows for a precise determination of the position of the metal projectile; however, it should be remembered that it may move within the maxillary sinus. The location of the metallic foreign body within the maxillary sinuses seems to be advantageous in relation to other craniofacial gunshots due to the possibility of a relatively easy and safe removal (both with and without the use of an endoscope) and the lack of known complications in the postoperative period.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/app112411809/s1, Supplementary S1. PRISMA 2020 Checklist; Supplementary S2. PRISMA 2020 for Abstracts Checklist; Supplementary S3. Qualification of PubMed and BASE articles at the screening stage; Supplementary S4. Qialification of articles from Google Scholar at the screening stage.

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