The rising challenge of mucormycosis for maxillofacial prostodontists in the Covid-19 pandemic: A literature review

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Abstract
Purpose: This review examines the importance of prosthetic rehabilitation after surgical treatment of mucormycosis in the context of expected increases in cases during the current COVID-19 pandemic.
Study selection: Google Scholar, Web of Science, Scopus, and PubMed databases were searched for relevant articles published between 2010 and 2021. Articles that provided a full description of prosthetic treatment after surgical treatment of mucormycosis were included in the review.
Results: Out of 30 articles describing orofacial prosthetic rehabilitation after surgical treatment of mucormycosis published during the 12-year target period, 19 reported patients with diabetes, two described mucormycosis as a post-COVID-19 complication, and 25 were reports from India. Most of the prosthetic treatments used a definitive obturator (63.3%) either alone or in combination with other forms of prosthetic rehabilitation. Other prosthetic strategies included an orbital prosthesis (26.6%), a facial prosthesis with or without a nasal replacement (16.6%), a surgical or interim obturator, a conventional complete denture, and a cast partial denture. Six articles (20%) mentioned the use of combined prosthetic rehabilitation involving multiple regions of the face and oral cavity.
Conclusion: Prosthetic rehabilitation after surgical treatment of mucormycosis is essential for the early restoration of oral function and facial esthetics. Given the aggressive nature of mucormycosis and the increasing number of cases reported during the COVID-19 pandemic, prosthodontists need to share their experiences with prosthetic rehabilitation of the defects that result from this disease to improve patients’ quality of life.
Keywords: Mucormycosis, COVID-19 pandemic, Diabetes mellitus, Maxillofacial rehabilitation

1. Introduction

Mucormycosis is a deep invasive mycotic infection caused by Mucorales fungi and typically affects people with a weakened immune system [1]. The most common conditions that predispose patients to mucormycosis are diabetes mellitus with or without ketoacidosis, hematological or other malignancies, transplantation, iron overload, corticosteroid use, trauma, prolonged neutropenia, and malnutrition [2]. The mode of contamination is the inhalation of fungal spores [3]. The infection can spread to the orbital and intracranial structures either by direct invasion or through the blood vessels. Oral mucormycosis usually affects the paranasal sinuses or nasal area, and severe infection of the paranasal sinuses can lead to palatal necrosis and/or ulceration [4]. Warning signs include cranial nerve palsy, sinus pain, proptosis, diplopia, periorbital edema, orbital apex syndrome, and palatine ulceration. Any of these symptoms should prompt additional testing, such as blood tests, imaging, exploratory ocular and/or sinus surgery, diagnostic endoscopy, and the start of antifungal therapy [5].

Uncontrolled diabetes mellitus is a major risk factor for mucormycosis [6]. Even patients who have a well-controlled diabetes with no underlying immunosuppressant risk factors are still at risk for mucormycosis infection [7]. Traditionally considered rare, this invasive fungal infection is beginning to become a concern in the COVID-19 pandemic era and with the increasing prevalence of diabetes globally [3]. Medical professionals are also facing additional challenges in the early diagnosis and treatment of this invasive fungal infection during the current COVID-19 pandemic.

Among the medical professionals involved in managing patients with mucormycosis, maxillofacial prosthodontists are responsible for prosthetic restoration of lost oral and maxillofacial structures, helping patients to socialize and have an acceptable quality of life after surgical treatment. The purpose of this review is to raise awareness about the expected increase in mucormycosis cases, the associated morbidities, and the role played by maxillofacial prosthodontists in rehabilitation during the COVID-19 pandemic.
2. Expected rise in mucormycosis cases during the COVID-19 pandemic

Globally, the reported prevalence of mucormycosis ranges from 0.005 to 1.7 per million population; however, the prevalence is nearly 80 times higher in India than in developed countries [5,8,9]. Diabetes remains the major risk factor for mucormycosis worldwide, with an overall mortality rate of 46% in diabetic patients who develop this fungal infection [6]. The prevalence of diabetes is rising in low-income and middle-income countries. For instance, 61.3 million Indian adults aged 20-79 years had diabetes in 2011, and this number is expected to increase to 101.2 million by 2030 [10]. China, Brazil, Japan, Mexico, Egypt, and Indonesia are also expected to show significant increases in their diabetes populations [8]. Therefore, it is likely that there will be a concomitant increase in the number of cases of mucormycosis.

In addition, the world continues to struggle against the COVID-19 pandemic, and there are few high-quality reports on its implications in dental practice [11]. Mucorales spores are likely able to germinate easily in patients with COVID-19 infection, possibly because of the low oxygen environment (hypoxia), high glucose levels (diabetes, new-onset hyperglycemia, steroid-induced hyperglycemia), acidic medium, high iron levels, and decreased phagocytic activity of white blood cells [3]. When combined with uncontrolled diabetes, the risk of mucormycosis is increased even further in these patients [12]. Therefore, mucormycosis appears to represent an intersection of two crises, namely COVID-19 and uncontrolled diabetes in the context of the pandemic.

In a systematic review of all cases of mucormycosis documented in patients with COVID-19 until April 9, 2021, John et al. [12] identified 41 confirmed cases in patients with COVID-19 and noted that 93% had diabetes and 88% were receiving corticosteroids. A second systematic review performed shortly after the first reported an almost three-fold increase in the number of published cases of mucormycosis in patients with COVID-19, with 82 cases (81.2%) reported in India, nine (8.9%) in the USA, three (3.1%) in Iran, and 19 (18.8%) in other countries [3]. The same study found a male predominance (78.9%) in people with active (59.4%) or resolved (40.6%) COVID-19 infection. The most commonly affected site was the nose and sinuses (88.9%), which was followed by rhino-orbital mucormycosis (56.7%) and rhino-orbital-cerebral mucormycosis (22.2%) [3].

Early and complete surgical treatment is recommended for mucormycosis whenever possible, in addition to antifungal medications and correction of underlying predisposing factors [1]. Considering the increasing number of cases and the predominant involvement of the orofacial region, we can expect to encounter more patients with orofacial defects after surgical treatment of mucormycosis during the current COVID-19 pandemic. Consequently, there is an urgent need to provide maxillofacial prosthetic rehabilitation for patients with mucormycosis to improve their quality of life. Increased awareness of the morbidity associated with this condition is also needed among dental and medical professionals.

Therefore, we conducted this review to determine the types of prosthetic rehabilitation provided after surgical treatment of mucormycosis, site specificity, immunocompromised states that may be associated with the occurrence of mucormycosis, and the worldwide distribution of reported cases.

3. Literature on prosthetic rehabilitation after surgical treatment of mucormycosis

3.1. Search strategy

The databases of Google Scholar, Web Of Science, Scopus, and PubMed were searched using the following MeSH terms: “zygomycosis,” “mucormycosis,” “Rhizopus,” “Mucor,” “Rhizomucor,” “Cunninghamhamella,” “Mycocladus,” “Absidia,” “Apophysomyces,” “Saksenaea,” “denture,” “prosthesis,” “obturator,” “rehabilitation,” “prosthodontic treatment,” and “prosthetic management.” The following related entry key words were used in different combinations using the Boolean operators “AND” and “OR” when searching the four databases: #1 (“zygomycosis,” OR “mucormycosis,” OR “Rhizopus,” OR “Mucor,” OR “Rhizomucor,” OR “Cunninghamhamella,” OR “Mycocladus,” OR “Absidia,” OR “Apophysomyces,” OR “Saksenaea”) AND #2 (“denture,” OR “prosthesis,” OR “obturator,” OR “rehabilitation,” OR “prosthodontic treatment,” OR “prosthetic management”). The bibliographies of the initially retrieved articles and the websites of the relevant journals were searched manually to further identify potentially eligible papers.

3.2. Inclusion criteria

All reports on maxillofacial prosthetic rehabilitation after surgical treatment of mucormycosis, which were published in English between 2010 and 2021 were included.

3.3. Exclusion criteria

Reports on fungal infections other than mucormycosis were excluded, as were those that did not provide a detailed description or photo documentation of the prosthetic treatment provided and those that were published in a language other than English.

3.4. Results

The details on the sites of the defect and types of prosthetic treatment provided are summarized in Table 1. A total of 30 articles [13,14,23-32,15,33-42,16-22] on prosthetic rehabilitation in the orofacial region after surgical treatment of mucormycosis published during the 12-year study period were reviewed. Of the 30 articles, 19 reported mucormycosis in diabetic patients, 2 described mucormycosis specifically as a post-COVID 19 complication, and 25 were reports from India. The majority of prosthetic treatments used a definitive obturator (63.3%) either alone or in combination with another prosthetic procedure. Other prosthetic treatments included an orbital prosthesis (26.6%), a facial prosthesis with or without a nasal replacement (16.6%), a surgical or interim obturator, a conventional complete denture, and a cast partial denture. Six reports (20%) mentioned the use of a combination of prosthetic rehabilitation strategies involving multiple regions of the face and oral cavity [13,14,19,36,38,41].

The locations of the defect and types of prosthesis delivered in these patients highlight the need for early restoration of oral function and facial esthetics to maintain quality of life. In most of the cases included in this review, the defect involved a large area of the face, both sides of the maxilla, or multiple regions. The large size of these defects and the patient’s acceptance of a more invasive procedure may limit the options for surgical reconstruction; therefore, prosthetic reconstruction is ideal for the predictable restoration of oral
<table>
<thead>
<tr>
<th>Author/reference</th>
<th>Year</th>
<th>Country</th>
<th>Defect extension</th>
<th>Prosthetic treatment</th>
<th>Underlying medical condition</th>
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<tbody>
<tr>
<td>Pruthi et al. [21]</td>
<td>2010</td>
<td>India</td>
<td>Exenteration of the right eye and right side hemi-maxillectomy</td>
<td>Hollow closed bulb obturator and a silicone orbital prosthesis</td>
<td>Diabetes mellitus</td>
</tr>
<tr>
<td>Hatami et al. [14]</td>
<td>2013</td>
<td>Iran</td>
<td>Resected portions included anterior part of hard palate, nasal septum, and conchae, left maxillary sinus, and orbital contents</td>
<td>Magnet-retained facial prosthesis including orbital prosthesis combined with maxillary obturator</td>
<td>Diabetes mellitus</td>
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<tr>
<td>Rathee et al. [15]</td>
<td>2013</td>
<td>India</td>
<td>Palatal Perforation</td>
<td>Surgical and interim obturators</td>
<td>Diabetes mellitus</td>
</tr>
<tr>
<td>Gowda et al. [16]</td>
<td>2013</td>
<td>India</td>
<td>Partial maxillectomy</td>
<td>Implant retained hollow bulb obturator with magnet attachment</td>
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<tr>
<td>Deshpande et al. [17]</td>
<td>2014</td>
<td>India</td>
<td>Facial defect</td>
<td>Facial prosthesis</td>
<td>Diabetes mellitus</td>
</tr>
<tr>
<td>Shah et al. [18]</td>
<td>2014</td>
<td>India</td>
<td>2 cases of reconstructed partial maxillectomy, with two remaining oronasal openings</td>
<td>Obturator prosthesis</td>
<td>Not reported</td>
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<tr>
<td>Vidyasankari et al. [19]</td>
<td>2014</td>
<td>India</td>
<td>Surgical exenteration of the left eye and left side hemi maxillectomy</td>
<td>Custom made orbital silicone prosthesis and a definitive hollow bulb obturator</td>
<td>Not reported</td>
</tr>
<tr>
<td>Faheemuddin et al. [20]</td>
<td>2014</td>
<td>Pakistan</td>
<td>Large central maxillary defect; involving all of the hard palate and a part of the left anterolateral ridge, sparing the soft palate beyond the posterior vibrating line posteriorly</td>
<td>Hollow bulb obturator</td>
<td>Diabetes mellitus</td>
</tr>
<tr>
<td>Pruthi et al. [13]</td>
<td>2014</td>
<td>India</td>
<td>Continuous orbital and maxillary defects</td>
<td>Orbital prosthesis attached to bulb of maxillary obturator with pin and socket of an electricity plug</td>
<td>Diabetes mellitus</td>
</tr>
<tr>
<td>Naveen et al. [22]</td>
<td>2015</td>
<td>India</td>
<td>Partial maxillectomy resulting in large oro-antral communication</td>
<td>Hollow bulb obturator</td>
<td>Diabetes mellitus</td>
</tr>
<tr>
<td>Shrivastava et al. [23]</td>
<td>2015</td>
<td>India</td>
<td>Mid-facial defect</td>
<td>Magnet retained two-piece maxillofacial prosthesis having hollow acrylic resin framework and an overlying silicone facial prosthesis</td>
<td>Not reported</td>
</tr>
<tr>
<td>Vasisht et al. [24]</td>
<td>2016</td>
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<td>Exenterated left eye</td>
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<tr>
<td>Punjabi et al. [25]</td>
<td>2018</td>
<td>India</td>
<td>Aramany Class VI maxillary defect</td>
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<td>Diabetes mellitus</td>
</tr>
<tr>
<td>Kaur et al. [26]</td>
<td>2018</td>
<td>India</td>
<td>Resected orbit</td>
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<td>Diabetes mellitus</td>
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<tr>
<td>Saker et al. [27]</td>
<td>2018</td>
<td>Iran</td>
<td>Lateral nasal defect</td>
<td>Nasal prosthesis</td>
<td>Acute myeloid leukemia, bone marrow transfer and chemotherapy</td>
</tr>
<tr>
<td>Manjunath et al. [28]</td>
<td>2018</td>
<td>India</td>
<td>Anterior maxillectomy</td>
<td>Interim obturator</td>
<td>Type II diabetes mellitus</td>
</tr>
<tr>
<td>Inbarajan et al. [29]</td>
<td>2018</td>
<td>India</td>
<td>Left maxillectomy defect extended into the buccal vestibule and lateral to the left hard palate with an adequate amount of alveolar ridge overlying the defect</td>
<td>Conventional complete denture</td>
<td>Type II Diabetes mellitus</td>
</tr>
<tr>
<td>Ikusika et al. [30]</td>
<td>2018</td>
<td>Nigeria</td>
<td>Aramany class VI defect</td>
<td>Interim obturater then definitive obturator</td>
<td>Diabetes mellitus</td>
</tr>
<tr>
<td>Abrol et al. [31]</td>
<td>2019</td>
<td>India</td>
<td>Sub-Total Maxillectomy (Aramany class IV)</td>
<td>Closed hollow bulb obturator</td>
<td>Not reported</td>
</tr>
<tr>
<td>Mani et al. [32]</td>
<td>2019</td>
<td>India</td>
<td>Bilateral maxillectomy</td>
<td>Complete hollow obturator</td>
<td>Diabetes mellitus</td>
</tr>
<tr>
<td>Jain et al. [33]</td>
<td>2019</td>
<td>India</td>
<td>Left orbital exenteration</td>
<td>Bicomponent hybrid orbital prosthesis</td>
<td>Diabetes mellitus</td>
</tr>
<tr>
<td>Gayathri Bandari et al.</td>
<td>2020</td>
<td>India</td>
<td>Aramany Class-IV defect</td>
<td>Fused two-piece hollow obturator</td>
<td>Post Covid-19 infection</td>
</tr>
<tr>
<td>Mohamed et al. [35]</td>
<td>2020</td>
<td>India</td>
<td>2 cases of partial and bilateral total maxillectomy</td>
<td>Delayed surgical obturator</td>
<td>Not reported</td>
</tr>
<tr>
<td>Rafique et al. [36]</td>
<td>2020</td>
<td>Pakistan</td>
<td>Combined extra-and intra-oral defect (Aramany type 2)</td>
<td>Intraoral obturator and extra-oral prosthesis retained together with magnetic attachments</td>
<td>Type II Diabetes mellitus</td>
</tr>
<tr>
<td>Satya et al. [37]</td>
<td>2020</td>
<td>India</td>
<td>Partial maxillectomy without oroantral communication</td>
<td>Cast partial denture</td>
<td>Kidney failure, transplant-ation and rejection</td>
</tr>
<tr>
<td>Eswaran et al. [38]</td>
<td>2021</td>
<td>India</td>
<td>External debridement of Nose and Paranasal sinuses and Orbit with Transoral Bilateral Maxillectomy and Right Frontal cranectomy</td>
<td>Repair with titanium mesh for cranial defect. Definitive obturator for oral defect</td>
<td>Covid 19 infection, hyperglyc-emia</td>
</tr>
<tr>
<td>Mishra et al. [39]</td>
<td>2021</td>
<td>India</td>
<td>Right class II-b (Brown classification [70]) maxillectomy defect</td>
<td>Delayed surgical obturator, interim obturator and open hollow bulb definitive obturator</td>
<td>Not reported</td>
</tr>
<tr>
<td>Shilpa et al. [40]</td>
<td>2021</td>
<td>India</td>
<td>Aramany class VI maxillectomy defect</td>
<td>Two-piece definitive obturator with magnetic attachment</td>
<td>Diabetes mellitus</td>
</tr>
<tr>
<td>Gowda et al. [41]</td>
<td>2021</td>
<td>India</td>
<td>Continuous orbital and maxillary defects</td>
<td>Combination prosthesis comprising of orbital prosthesis and obturator with custom-made retentive attachment with brass cylinder and housing</td>
<td>Diabetes mellitus</td>
</tr>
<tr>
<td>Gaur et al. [42]</td>
<td>2021</td>
<td>India</td>
<td>Bilateral subtotal maxillectomy</td>
<td>Implant supported obturator</td>
<td>Diabetes mellitus</td>
</tr>
</tbody>
</table>
function and facial esthetics in these patients. In addition, surgical reconstruction is generally considered a risky endeavor in a patient who has recovered from mucormycosis due to comorbid conditions [43]. For these patients, a prosthesis that can be easily removed is advantageous in checking for the recurrence of infection at the site of surgery, which could help in early diagnosis and treatment before complications develop [41]. Therefore, rehabilitation with maxillofacial prosthesis is a safe, inexpensive, and fast alternative with satisfactory outcomes, especially for patients with advanced age and compromised health [14].

Large-sized maxillectomy defects often result after surgical treatment of mucormycosis, and the duration of healing in such defects is determined not only by the aggressive nature of the lesion, but also by the postoperative care [39]. As confirmed by the majority of reports in this review [16,19-22,25,31,32,34,39], weight reduction is critically important when the prosthesis is suspended without much remnant bone and tooth support. As a result, in such cases, a hollow bulb design should be used [17,23,24,27,32,36,39-42]. A lighter obturator improves suspension cantilever mechanics, prevents over-stressing of the remaining supporting structures, and increases retention [44]. The open-hollow bulb design is also preferred over the closed-bulb design because it is lighter in weight, easier to fabricate, and produces noticeably better articulation [39]. However, it should be used when the weight of the prosthesis is a major concern [39], and only with regular follow-up because the open design tends to accumulate mucous secretions, which can be a source of infection [32]. Remote implant-bone anchorage using pterygoid, zygomatic, and nazalus implants was also reported to be a more effective solution than conventional implants in improving prosthesis retention and support [42].

The use of soft liners in a definitive obturator has the advantage of reducing pressure on defect areas by providing a cushioning effect between the prosthesis and the defect margins. In addition, the flexibility of these materials allows for easier placement of the obturator into retentive undercuts [45]. However, in a patient with a history of mucormycosis, the use of soft liners in a prosthesis that contacts the nasal mucosa is not recommended [18]. This is due to their higher risk of fungal contamination compared to acrylic resins [46]. As a result, if they are unavoidably used, the maxillofacial prosthodontist should always maintain long-term follow-up and visual examination for any signs of lesion recurrence [18].

Another matter of concern confirmed by this review is the relatively high prevalence of Aramany class VI defects in patients with mucormycosis, despite their minimal frequency in maxillofacial patients [47]. As such, general practitioners may not be familiar with the rehabilitation protocol, which could lead to delays in early restoration in these patients. These defects are single, anterior to the remaining teeth, and difficult to manage [48]. Problems related to masticatory function, speech, deglutition, and facial esthetics often exist [49]. Because the obturator bulb is located far away from the posterior abutments in these patients, without adequate support and retention of the prosthesis, the anterior segment tends to cantilever into the defect. This may induce discomfort, compromise the stability of the prosthesis, and transmit heavy stresses to the abutment teeth [49]. On the other hand, the angulations of the remaining abutment teeth, as well as the anatomy of the defect, influence the path of insertion of the prosthesis. Because these patients are psychologically and functionally disadvantaged following surgery, a multidisciplinary approach that includes psychological and prosthodontic considerations should be used [48].

When treating mucormycosis, it is crucially important to keep in mind that maxillectomy defects are always prone to bacterial superinfection by oral and respiratory commensals [30]. Even during rehabilitation, a superinfection can still occur. Combined with the risk of recurrence of the primary mycosis, patients should be scheduled for long-term follow-up appointments [30].

For rehabilitation of orbital defects caused by mucormycosis, a direct contact of adhesive-retained silicone prosthesis is not recommended because of the risk of accelerated deterioration of the prosthesis and to minimize the risk of recurrence of infection [26,33]. Although the placement of implants in the orbit has been documented, there is an increased risk of failure due to soft tissue infections, decreased vascular perfusion, poor remodeling capacity of the bone-implant surface, and lack of stabilizing bone volume in proximity to the frontal sinus [50-52]. In addition, medical conditions such as uncontrolled diabetes, immunodeficiency diseases, and irradiation limit the use of osseointegrated implants [53,54]. Therefore, implant placement in an orbital defect should be planned carefully in patients who recover from mucormycosis, since most of these patients have a compromised immune system and poor general health. If implants are ruled out, an alternative option using a heat-polymerized conformer substructure that makes use of the defect undercuts for retention was suggested by Kaur et al [26]. Digital fabrication of the conformer is also possible, and severe undercuts can be virtually blocked out to allow for the smooth insertion and removal of the prosthesis [33]. It can be hollowed easily to reduce the overall weight of the prosthesis and facilitate hygiene procedures [33]. Importantly, it would minimize the tissue contact of silicone, thus minimizing the risk of tissue irritation and recurrence of infection [23].

For patients who have continuous orbital and maxillary defects with missing anatomic undercuts, an orbital prosthesis can be attached to the obturator with a pin and socket of an electricity plug or using magnetic buttons that provide satisfactory retention and do not necessitate the use of adhesives or spectacles [13]. The only limitation of these methods is that patients must have manual dexterity to accurately seat the prosthesis. However, in practice, this can be learned quickly. There may also be corrosion or loss of magnetism over time [55]; however, unlike other commonly used magnets, these magnetic buttons are inexpensive and readily available. As a result, these can be easily replaced without damaging or replacing the existing prosthesis. Gowda et al. [41] described another method of custom-made retentive attachment between the obturator bulb and the orbital prosthesis for rehabilitation of a defect secondary to sino-orbital mucormycosis utilizing a brass cylinder and housing. This non-rigid attachment helps reduce the movement of the extraoral prosthesis when the obturator functions by providing a movable joint between both components. This is especially helpful for complex defects with compromised bony and dental support, where an increased movement of the obturator is expected. In case of large midfacial defects secondary to mucormycosis, Shrivastava et al. [23] described an approach using a magnet retained two-piece maxillofacial prosthesis with a hollow acrylic resin framework and an overlying silicone facial prosthesis. This approach aimed to avoid invasive techniques leading to recurrence of lesions and help distribute the weight of the prosthesis and enhance retention with magnets and adhesive as a mutual means of retention. Additional retention for the facial prosthesis in such complex defects can be obtained using
eyeglasses stabilized by an elastic band around the back of the head from one earpiece to the other [14]. A silicone eye prosthesis extending from the medial side into an adjacent nasal defect area can be a source of infection due to silicone porosity. Therefore, Dhiman et al. [56] recommended the application of an antifungal medication, such as nystatin cream, to the prosthesis surface coming in contact with the nasal/oral cavity.

In this review, the majority of cases have been reported in India, which has one of the largest diabetic populations in the world [10]. Since diabetes is a major risk factor for mucormycosis in India (54-76%) [57], it was the underlying disease in most of the reviewed reports. Due to the lack of regular health check-ups in the Indian population, mucormycosis unmasked diabetes in 43% of patients from North India [58], 40% of patients from Western India [59], and 24% of patients from South India [60]. These findings highlight the importance of regular health screenings in the Indian population for the early diagnosis of diabetes, thereby preventing complications such as mucormycosis.

Among possible reasons for the mucormycosis outbreak during the second wave of COVID-19 pandemic are the lack of medical grade oxygen supply chain and the use of industrial oxygen, often inadequately sanitized, to compensate for this shortage [61]. Furthermore, both non-humified oxygen and steam inhalation can cause mucosal injury, making Mucorales infection easier to spread. Owing to a lack of disposable oxygen humidifiers, reusable ones have been employed, posing a risk of nosocomial infections, particularly when maintenance is inadequate, and water is undistilled [62]. As a result, careful sanitation and handling of oxygen gas cylinders prior to usage in the hospital/home is critical. Pathogens can survive for hours to months on several hospital surfaces. Therefore, decontamination of high-contact surfaces, regular hand washing, and wearing face masks should always be adopted. The irrational use of glucocorticoids, multivitamins containing zinc and iron, and broad-spectrum antibiotics in COVID-19 cases are implicated factors, and therefore, should be discouraged to avoid the risk of acquiring mucormycosis [61]. Voriconazole, which is commonly used as an antifungal prophylactic to avoid opportunistic systemic fungal infections, is inefficient against Mucorales and has been linked to outbreaks of mucormycosis [63]. Difficulties in appropriate care of patients with chronic medical conditions predisposing to mucormycosis at the time of lockdowns were also associated with a spike in reported cases [64]. As post-COVID-19 patients are also at risk for acquiring mucormycosis, they should stay in a well-ventilated environment and keep away from decaying organic materials, especially during the first three months post-treatment [65,66].

Despite the increasing number of mucormycosis cases, particularly in India, only two reports in this review were linked to COVID-19 infection [34,38]. This can be explained in terms of prioritizing COVID-19 concerns over seeking prosthetic rehabilitation during the pandemic. In addition, the lockdown measures and lack of transportation in some rural areas may have also significantly impacted the admission of patients who followed time-bound treatment schedules, including maxillofacial rehabilitation [67]. The scarcity of these reports should alert the prosthetic community to the importance of providing prosthetic rehabilitation and sharing experiences with these patients in light of the increasing number of cases worldwide. Given the difficulties in making a microbiological or histological diagnosis, especially in a pandemic setting, the reported cases may be an underrepresentation of the true burden of mucormycosis, which could have serious implications for not only patients, but also medical and dental personnel in the near future.

4. Recommendations from a prosthodontic perspective

Based on the findings of this review, we strongly recommend the following:

1. Before beginning treatment for mucormycosis, the patient should be assessed by a medical specialist, ideally an endocrinologist, to ensure adequate protection with long-acting insulin and a systemic antifungal to prevent future fungal infection during and after treatment [56,68].
2. Establishing a channel that allows for easy communication among medical staff is highly recommended to solve the problems of remote areas with restricted services, especially during the lockdown measures of the pandemic. This would allow for early diagnosis and intervention before complications develop.
3. Patients with diabetes, especially if uncontrolled, should be monitored carefully for signs of ulceration or exposed necrotic bone after delivery of a prosthesis, and they should be encouraged to see a specialist to help control their diabetes and avoid complications.
4. Patients who have recently recovered from COVID-19 infection should be monitored carefully, regardless of whether they have a history of mucormycosis, and should be well-sterilized before delivery, especially if an immediate surgical obturator is used, because it will be in contact with an open wound.
5. Patients at risk of mucormycosis should be encouraged to report any signs of ulceration, visual disturbance, or facial or orbital swelling.
6. Care of the prosthesis by daily washing with 1% chlorhexidine solution [69] and oral hygiene procedures should be stressed at every visit, especially in high-risk patients. In addition, follow-up with the dentist for polishing and buffing should be performed regularly.
7. If soft materials such as resilient liners are used on the fitting surface of the obturator, frequent cleaning is recommended because of the higher risk of fungal contamination.
8. Maxillofacial prosthetists should make every effort to share their experiences of rehabilitation of patients with mucormycosis after surgery, especially through online means during the pandemic era.
9. Finally, there is a need for more specialists in the field of maxillofacial prosthetics worldwide to treat the increasing number of patients requiring treatment for maxillofacial defects, whether due to COVID-19-associated mucormycosis or other factors.

5. Conclusion

Early prosthetic rehabilitation after surgical treatment of mucormycosis is essential for the optimal restoration of oral function and facial esthetics. In light of the increasing number of mucormycosis cases reported during the COVID-19 pandemic and the aggressive nature of this condition, there is an urgent need to raise awareness among susceptible patients and prosthetists to share their experiences with prosthetic rehabilitation of the resulting orofacial defects to improve the quality of life of our patients.
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Conflicts of interest

The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article.

References


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