Review Article

Biomechanical phenomena involved in facial trauma: an integrative review

Fenômenos biomecânicos envolvidos nos traumas faciais: uma revisão integrativa

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■ **ABSTRACT**

Introduction: Trauma is defined as an injury that leads to changes in an individual's structure due to the energy exchange between tissues and the environment. Because of its location, the maxillofacial skeleton is commonly affected by trauma. Besides, existing studies that seek to address the theme commonly do so in a fragmented way, focused only on a bone structure. Therefore, the present study was proposed as an attempt to bridge this gap in today's literature. **Methods:** The search was performed on the platforms PubMed, LILACS, and *Cochrane Library* using the descriptors: *"biomechanical phenomena," "facial injuries"* and *"fractures, bone,"* finding 321 articles. The inclusion criteria were: studies published in the last five years, available in full, in English or Portuguese. After using these filters, 50 studies were found, and after analytical reading of the title and available summary, 44 studies were excluded. **Discussion:** The mandible is more vulnerable to lateral than frontal impacts; it was shown that in lateral impacts, the most significant stress force was exerted on structures ipsilateral to the impact. It was also demonstrated that dentition's partial or total absence presented greater stress forces on the condyle. In the orbit, there are mainly edge fractures and globe/floor fractures. The first are fractures that tend to be smaller and anteriorly arranged, whereas those on the floor would be the opposite. **Conclusion:** In short, several factors can influence the occurrence of facial trauma; among them are the biomechanical phenomena involved.

Keywords: Biomechanical phenomena; Facial bones; Facial injuries; Bone fractures; Oral surgery.

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■ **RESUMO**

Introdução: O trauma é definido como um agravo que leva a alterações na estrutura do indivíduo por causa da troca de energia entre os tecidos e o meio. Por causa da sua localização, o esqueleto maxilofacial é comumente acometido por traumas. Além disso, os estudos existentes que buscam abordar a temática comumente a abordam de maneira fragmentada, focada apenas em uma estrutura óssea. Portanto, o presente estudo foi proposto como tentativa de minorar essa lacuna existente na literatura hodierna. **Métodos:** A busca foi realizada nas plataformas PubMed, LILACS e *Cochrane Library* utilizando os descritores: "*biomechanical phenomena*", "*facial injuries*" e "*fractures, bone*", encontrando 321 artigos. Os critérios de inclusão foram: estudos publicados nos últimos 5 anos, disponíveis integralmente, nos idiomas inglês ou português. Após a utilização desses filtros foram encontrados 50 estudos, e após leitura analítica do título e do resumo disponível, foram excluídos 44 estudos. **Discussão:** A mandíbula é mais vulnerável aos impactos laterais do que frontais, evidenciou-se que nos impactos laterais a maior força de estresse era exercida em estruturas ipsilaterais ao impacto. Também se demonstrou que a ausência parcial ou total de dentição apresentavam maiores forças de estresse ao côndilo. Na órbita há principalmente fraturas de borda e fraturas de globo/assoalho. A primeira são fraturas que tendem a ser menores e dispostas anteriormente, já as de assoalho, seria o inverso. **Conclusão:** Em suma, existem vários fatores que podem influenciar na ocorrência do trauma de face, dentre elas estão os fenômenos biomecânicos envolvidos.

Descritores: Fenômenos biomecânicos; Ossos faciais; Traumatismos faciais; Fraturas ósseas; Cirurgia bucal.

INTRODUCTION

Trauma is defined as an injury that leads to changes in an individual's structure due to the energy exchange between tissues and the environment[1]. Because of its location, the maxillofacial skeleton is commonly affected by trauma[2]. Epidemiology varies according to the demography, geography, and economics of the place where the study is carried out[3]. Automobile accidents have been one of the leading causes of facial fractures, in addition to aggressions or falls[3].

These types of fractures can often be associated with severe concomitant injuries, such as traumatic brain injuries[4]. This relationship emphasizes the need to perform a careful physical examination, complemented by imaging and hematological exams, and to research the history of trauma to ensure that no injuries are neglected and the need for the evaluation of a multidisciplinary team for the proper treatment of the patient[4].

However, some studies report the reduction of traumas related to these factors in some locations; it is assumed that the improvement of traffic safety laws and safer roads are why this change[3].

Given the complexity of the trauma, the average hospital stay is seven days, with the most affected site being the middle third of the face[5] and ratifying that the importance of knowing the epidemiology of maxillofacial trauma is essential to improve the quality of care and promote, mainly, strategies for its prevention[2].

Studying the biomechanics of trauma is also essential at the time of diagnosis for proper treatment. However, it is challenging to generate a practical and ethically acceptable study to provide valid information[6].

An adequate understanding of the injured region's anatomy, along with the trauma history, also knowing its biomechanics, helps when planning treatment[7].

Thus, there is little data in the literature on the subject due to ethical limitations. Besides, studies that seek to address the theme commonly do so in a

fragmented way, focused only on a bone structure. Therefore, the present study was proposed as an attempt to bridge this gap in today's literature.

OBJECTIVE

This work aims to review the current literature about the biomechanical phenomena involving facial trauma.

METHODS

It is an integrative review, whose guiding question elaborated for the beginning of the search was: "What are the main factors that influence the facial trauma kinematics?".

The search was carried out in July 2019 on the PubMed, LILACS, and Cochrane Library platform using the descriptors present on the "health science descriptors (DECS)" platform: "biomechanical phenomena," "facial injuries" and "fractures, bone," thus finding 321 articles.

The inclusion criteria were: studies published in the last five years, available entirely on the web, in English or Portuguese. After using these filters, 50 studies were found, of which, after analytical reading of the title and abstract available on the platform, 44 studies were excluded.

Most of them were excluded because they only addressed surgical treatment, some were excluded because they were literature reviews, since studies of the type of reviews and editorials were not considered to be included in the sample, and one study presented Mandarin as a language, being taken from the sample. Thus, six articles were selected to compose the review sample (Chart 1).

Chart 1. Summary of articles published in the databases: PubMed, Cochrane Library and LILACS (Fortaleza / CE, 2020).

Platform	Found	Selected	Sample
PubMed	321	50	6
Cochrane Library	0	0	0
LILACS	5	0	0

RESULTS

The selected articles were organized in a table so that the topics considered relevant for each study were exposed, such as author and date of publication, type of study, study subjects, objectives, language, and bone structures affected, as set out in Table 2.

Regarding the dates, there were three articles from 2015, the most recent was from 2018 and the others from 2016 and 2017, thus obeying the inclusion criteria, which allow the inclusion of articles published in the last five years, and they were not found in 2019 articles of the year.

In the studies that comprised the sample, the majority (3/5) used 3D models for the analysis, while the other studies used human and human cadavers while still alive - when they were case reports. All studies were published in English.

Therefore, based on the articles' reading, they were divided into three categories to be discussed with more outstanding care:location of the impact as determinants of the fracture, the influence of the molars for the injury, importance of the clinic for the proper management of trauma face

DISCUSSION

Impact site as determinant for fracture

Several factors can predispose to facial trauma, such as male gender, advanced age[8,9]; and sports practice, for example, sports such as basketball, football, and baseball[10]. Besides these, there is no doubt about the influence of the place where the impact occurred for the predisposition to certain fractures, as evidenced by the studies that composed the sample addressing fractures in the mandible, orbit, and styloid process.

Mandible

Regarding the mandible, in the study by Liu et al., 2018[11], two regions of this bone structure were mainly addressed: the mandible and the angle's condyle. Observing that the chin region's impacts exerted more significant stress under the condyle, while lateral impacts exerted greater stress on the condyle and, subsequently, on the mandible angle[11].

The mandible is more vulnerable to lateral than frontal impacts, with greater impact resistance only the nasal and zygomatic bones, whose areas are more sensitive[12].

Besides, it was evidenced that in the lateral impacts, the most significant stress force was exerted in structures ipsilateral to the impact, being, therefore, in the lateral impact, the condyle, followed by the ipsilateral angle, more susceptible to fractures[11].

One explanation for this finding is the ability to dissipate stress and absorb it by the bone structures closest to the impact, being the structures contralateral to the impact less susceptible to fractures[11].

Another study, by Santos et al., in 2014[13], agreed with the one mentioned above, concerning condyle fractures, whose impact exerted on the symphysial and parasymphysial region presented a more significant burden agreeing about greater stress in regions ipsilateral.

Chart 2. Distribution of information from the articles that comprised the sample (Fortaleza / CE, 2020).

Author	Subjects	Study type	Objectives	Language	Bone structures addressed
Liu et al., 2018[11]	3D virtual master mandible model	Original article	This study examined the distribution of stress to the mandible without third molars and with different IM3 orientations resulting from a 2000-Newton test of anterior midline impact force or mandible body.	English	Mandible
Patel et al., 2017[16]	Study with cadavers. 10 orbits of 5 heads.	Original article	To elucidate and define the biomechanical factors involved in orbital floor fractures.	English	Orbit
Kang e Chung, 2015[19]	Male, 52 years old	Case report	Description of a case report with literature review.	English	Orbit
Tuchtan et al., 2015[15]	Postmortem corpses and 3D models	Original article	Evaluate the dispersion of force not only in the mandible, but also in the brain.	English	Mandible
Santos et al., 2015[13]	3D Models	Original article	Analyze stress distributions from traumatic loads applied to the symphyseal, parasympathetic areas and regions of the mandibular body, in the edentulous mandible of the elderly using finite element analysis (FEA).	English	Mandible
Gayathri et al., 2016[21]	Female, 36 years old.	Case report	Clarify the consultations mentioned above. The article also aims to explore the biomechanics involved in such combined fractures and analyze treatment probabilities.	English	Styloid process

Another type of condyle fracture is the guardsman fracture, a bilateral fracture of these structures concomitant with the fracture of the mandible's symphysis, being the injury mechanism often a fall without the attempt to cushion the impact with the hands, as in the elderly or individuals after a syncope[14].

Among the directions of the impact, as evidenced by Tuchtan et al., in 2015[15], the uppercut simulated blow, popularly called "hook," generates greater forces than the frontal and lateral impacts, even affecting the occipital bone, with more significant damage to the chin.

Orbit

Another area addressed in the articles that comprised the sample was the orbit, with mainly two presentations, edge fractures and globe/floor fractures. The first refers to fractures that tend to be smaller and anteriorly arranged; on the floor, the opposite occurs1616. the floor

It is assumed that the relationship between the fracture size dimension and its disposition on the anteroposterior axis is due to the decrease in the thickness of the orbital bones, which tend to decrease as they turn posteromedially, as demonstrated by Patel et al. in 2017[16].

Besides, orbital floor fractures can be divided into blow-out and blow-in. The first, when there is an invagination of bone fragments into the maxillary sinus, usually occurring in major trauma to the zygoma or orbit. Blow-in, on the other hand, occurs when fragments turn into the eye socket, occurring when there is an increase in pressure in the maxillary sinus, as in a situation where the tire bursts close to the patient's face[17].

There are two main theories for blow-out orbit fractures, the hydraulic and buckling theory. The first one states that the eyeball's hydraulic pressure is transmitted to the orbit wall, generating fracture of the orbit[18]. The buckling theory states that the direct impact on the lower edge of the orbit can cause a temporary deformation of it without fracturing it; however, the impact is transmitted to the floor of the orbit[18]; it may be accompanied by clinical signs, such as hematoma, lower eyelid edema and irregularities in the lower edge of the orbit[19].

Styloid process

Another structure is added that was addressed by the articles that composed the sample: the styloid process. Lesions can be divided into intrinsic and extrinsic. The intrinsic originates from the muscles inserted in this structure may occur due to spasms, convulsions, laughter, and excessive coughing. On the other hand, the extrinsic is an impact on the structure in situations where it is already prone to fracture, or even in the anterior region of the mandible[20,21].

Influence of molars for injury

Another study reports that during a lateral impact, the presence of the impacted third molar can decrease the risk of fracture in the condyle; however, it can increase the risk of fracture of the ipsilateral mandibular angle[11].

According to a meta-analysis published in 2017, the risk of fractures of the mandible angle in individuals with third molars is almost three times higher than in individuals who do not have this dentition[22]. This information has been ratified by Tuchtan et al. (2015) [15], a study in which it showed that it presented greater stress forces in the condyle in the partial or total absence of dentition. Furthermore, in the study by Brucoli et al., In 2019[23], it was also seen that the complete eruption of the third molars is associated with condylar fractures.

When a frontal impact is mentioned, the risk of condyle fracture is greater than that of angle, regardless of the presence of the third molars11. Another relevant analysis factor is the tooth's impaction since fully impacted teeth reflect a greater tension in the mandible than those partially impacted[11]. Although, in the study by Brucoli et al.(2019)[23], partially impacted teeth were associated with angle fracture. However, these teeth' angulation does not present significant differences concerning the distribution of forces in the mandible when subjected to impact[11].

Importance of the clinic for the proper management of facial trauma

Regarding the importance of clinical analysis, it was evidenced in the study by Patel et al. (2017) [16] that although computed tomography is essential for the diagnosis of orbital fractures, an ophthalmological examination is also necessary, since, among the nine orbital fractures, computed tomography only showed 3[16].

In the study by Rothweiler et al., In 2018[24], they showed the importance of a thorough clinical analysis, taking into account the severity of the injury and the patient's age, in multiple trauma patients. The ideal time for surgery should be individual because of the patient's stability and the edema that could harm the surgical result.

A multidisciplinary team's importance in the treatment of facial fractures is undoubted, as they are complex fractures that can affect the central nervous system and may require the approach of a neurosurgeon. The simultaneous performance of the maxillofacial surgeon with the neurosurgeon may be beneficial during treatment[25].

CONCLUSION

In short, it is concluded that several factors can influence the occurrence of facial trauma; among them are the biomechanical phenomena involved. The present study demonstrated that the site of the impact is an essential predictor of the fracture occurrence site, with the mandible condyle being a place of more significant stress, especially in a frontal impact.

Another finding evidenced by the study was the ability of third molar teeth to influence the greater predisposition to certain fractures, depending on their implantation.

Besides, the clinic's importance and the multidisciplinary management of these lesions are ratified to establish more diligent diagnoses, more efficient treatments, and adequate prevention measures.

COLLABORATIONS

TMV	Analysis and/or data interpretation, Data Curation, Writing - Review & Editing
TMV	Analysis and/or data interpretation, Data Curation, Methodology, Writing - Review & Editing
FACV	Supervision, Writing - Review & Editing
MATN	Supervision, Writing - Review & Editing

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