Journal of Advances in Medicine and Medical Research

34(22): 255-266, 2022; Article no.JAMMR.92411
ISSN: 2456-8899
(Past name: British Journal of Medicine and Medical Research, Past ISSN: 2231-0614, NLM ID: 101570965)

A Comprehensive Review of the Pros and Cons of Definitions of Radiation-Induced Trismus

Efsun Somay [a], Busra Yilmaz [b], Ahmet Kucuk [c] and Erkan Topkan [d*]

[a] Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Baskent University, Ankara, Turkey.
[b] Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Baskent University, Ankara, Turkey.
[c] Department of Radiation Oncology, Mersin City Hospital, Mersin, Turkey.
[d] Department of Radiation Oncology, Faculty of Medicine, Baskent University, Adana, Turkey.

Authors' contributions

All authors contributed significantly and equally; and all authors approved the final form of the manuscript.

Article Information

DOI: 10.9734/JAMMR/2022/v34i2231599

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/92411

Review Article

Received 12 July 2022
Accepted 24 September 2022
Published 27 September 2022

ABSTRACT

Radiation therapy is the most common cause of cancer-related trismus. Radiation therapy can lead to fibrosis and hypoxia in the temporomandibular joint ligaments, synovial fluid, and masticatory muscles. This makes it difficult for patients to move their jaws and eventually leads to restricted mouth opening. This devastating complication is called radiation-induced trismus, which occurs after radiation therapy in patients with head and neck cancers and affects their daily routine functions such as eating, speaking, chewing, swallowing, and oral hygiene habits, as well as impairs their psychosocial communication and decreases their quality of life. The evaluation in radiation-induced trismus determination is basically performed by measuring the maximum mouth opening. Previous studies evaluating radiation-induced trismus have used many maximum mouth opening cut-off values such as 40 mm, 35 mm, 30 mm, and 20 mm. The fact that no common and valid language is used to establish cut-off values means that the impact and prevalence of this serious complication are not fully revealed. In the absence of a widely accepted maximum mouth opening cutoff value or range for radiation-induced trismus definition that applies to all patients with head and neck cancers, a patient may be labeled as trismus in some studies but non-trismus in

**Corresponding author: E-mail: docdretopkan@gmail.com;*

others. Preventative and therapeutic treatments may be disregarded in certain patients as a result of such ambiguity, which may cause severe declines in affected patients' medical, psychological, social, sexual, and financial status. With a focus on the detrimental effects of such competing definitions on patient management, the current review aims to carefully compare and evaluate the pros and cons of each definition of radiation-induced trismus.

Keywords: Radiation therapy; head and neck cancer; trismus; maximum mouth opening; quality of life.

1. INTRODUCTION

Head and neck cancers (HNC) are the sixth most prevalent malignancy in the world, with about 600,000 new cases diagnosed each year [1], with squamous cell cancers comprising nearly 90% of all histological types of HNCs [2]. Although the median age of patients is roughly 60 years, a growing tendency of young-onset HNC in those younger than 45 years has been recorded globally, which may be attributable to an increase in the number of young-onset malignancies of the oral cavity and oropharynx [3,4]. About 80% of HNC patients receive radiation therapy (RT). Moreover, definitive or postoperative RT has been linked to an increased incidence of long-term second main tumors in a variety of malignancies [5-7], adding to the already growing number of HNC patients. Despite significant advancements in RT planning and administration techniques, a sizeable portion of patients experience severe radiation-related complications [8]. Trismus, dysphagia, xerostomia, dysgeusia, ageusia, dental disease, orofacial pain, oral infections, and osteoradionecrosis are some of these morbidities [9] (Fig. 1). Reducing complications and maintaining quality of life (QoL) metrics has evolved into a crucial long-term goal for an increasing number of survivors as survival rates increased.

Despite its significant adverse consequences, there are few investigations into radiation-induced trismus (RIT). RIT is a catastrophic side effect of RT or concurrent chemoradiotherapy (C-CRT) that affects 5% to 69% of HNC patients, depending on the primary tumor type, its extension to neighboring tissues, and the stage of cancer [10]. A maximum mouth opening (MMO) of ≤ 35 mm is commonly used as the RIT cutoff [11]. It might occur three months after treatment or 12 to 48 months following RT or C-CRT. Regrettably, there is substantial disagreement in the literature about how to calculate MMO and, ultimately, RIT. This is due to the challenges associated with MMO measurement and RIT diagnosis, as well as a dearth of unambiguous, impartial, and universally accepted standards, which make it challenging to forecast, identify, and prevent this terrible complication. This clinical picture is challenging in the absence of particular questionnaires to evaluate and describe the effects of this severe RIT-specific complication on the QoL of HNC patients.

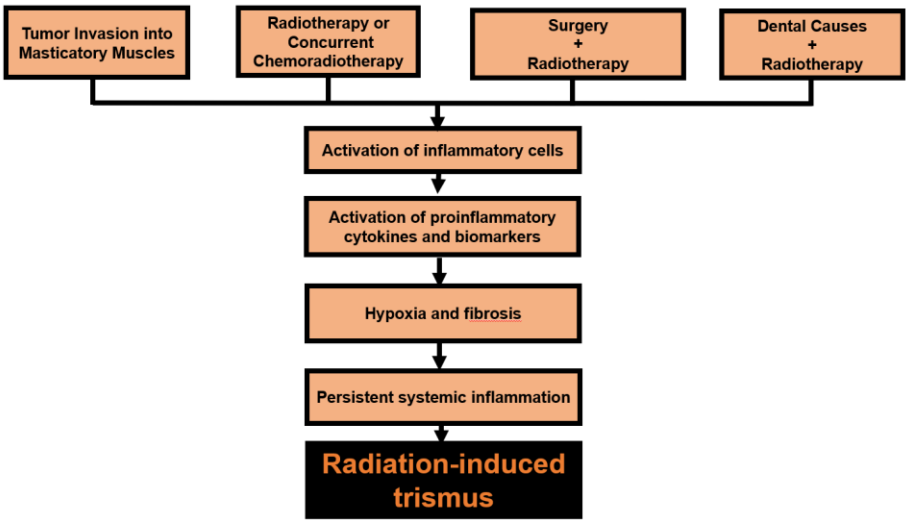

Fig. 1. Causes and mechanism of radiation-induced trismus

Since age, gender, and race have a significant impact on both the MMO and the typical mouth-opening range, these definitions have been debated aggressively in earlier studies [12–15]. For example, the typical MMO was determined to be 44.8±9.4 mm in males and 39.2±10.8 mm in women in a study of 299 individuals by Carlsson and Svardstrom et al. [16]. On the other hand, Agerberg found that MMO ranged from 42 to 75 mm in females and 44 to 77 mm in males [17]. Determining the degree of restricted mouth opening in the diagnosis of trismus has proven difficult due to the ambiguity in establishing a normal mouth opening range, leading to the evolution of numerous trismus classifications. Consequently, the impact of a problem affecting HNC patients' QoL, such as RIT, is concealed, and the actions to be done to diagnose and overcome it are missed. Hence, the objective of this review is to comprehensively discuss the pros and cons of the current MMO measurement methodologies that were employed to assess RIT.

2. LITERATURE RESEARCH AND REVIEW METHODOLOGY

The objective of this review is to compare and assess each definition of radiation-induced trismus in detail, weighing its advantages and disadvantages. For this purpose, literature searches were conducted on PUBMED using the keywords "trismus", "radiation-induced trismus", and "trismus definition" to find studies that had been published between January 1970 and August 2022. Duplicate studies were eliminated, and the results were presented in their original publication format, with no additional statistical analysis.

3. DEFINITIONS OF TRISMUS AND THEIR COMPARISONS

Trismus, or restricted mouth opening, can result from radiation-induced fibrosis following definitive or postoperative RT or tumor growth into the masticatory apparatus. Daily oral intake, dental care, social interactions, oncologic monitoring, and dental treatment could all be affected [18-22]. In older investigations, several MMO cutoffs for trismus were developed according to the dental state of the individuals. For instance, the MMO cutoff was set at 35 mm for dentulous patients and 40 mm for edentulous patients in research by Louise Kent et al. in 40 HNC patients who had RT [23]. However, Lindblom et al. [24] and Steiner et al. [25] classified trismus according to its severity and discovered various cutoff values, such as >35 mm for moderate trismus and 20 or 25 mm for severe trismus. Grading systems have also been used to characterize and assess the severity of trismus, like grades 2, 3, and 4 for an MMO opening of 10 to 20 mm, 5 to 10 mm, and less than 5 mm, respectively [23].

In the absence of impartial and distinctive metric assessments, the MMO cut-off values for the trismus definition appear to have been chosen arbitrarily [26]. Because of the multiplicity of cutoff points employed, the risk factors and effectiveness of trismus therapy cannot be systematically studied, and the research findings are complicated to comprehend. The broadly adopted trismus definition cut-off point for trismus definition in HNC patients is 35 mm or less [18,27-29]. The restrictions that people with HNC described served as the foundation for this threshold in the most widely cited study by Dijkstra et al. [11]. This definition's specificity and sensitivity scores were 71% and 98%, respectively. The MMOs were determined separately depending on the type of oncological treatment (no treatment, surgery only, RT only, or surgery and RT) in this study, which included 671 patients with HNCs. Patients were divided into three groups: dentulous, partially edentulous, and edentulous. They found that patients who received only RT had mouth-opening issues at a lower MMO (33 mm) than patients who only had surgery (37 mm) [11]. The OraStretch® Range-of-Motion scale for patients with MMOs up to 52 mm and calipers for patients with MMOs greater than 52 mm were used for all of these measurements. However, measurements were carried out by a number of medical experts, so there was a chance for interobserver variations. Furthermore, the same measurement technique was used on patients who were dentulous, partially edentulous, and edentulous, and an average trismus cutoff metric was proposed for all patients rather than a specific cutoff for each situation. Therefore, the true differential impact of trismus on functionality and QoL in patients at the edge of the calculated cutoff value cannot be appropriately interpreted in comparison to the patients diagnosed with trismus. From a different perspective, failure to use a specific questionnaire conjoined with MMO measurements to evaluate how this complication affects QoL will obscure the precise clinical picture of patients in the trismus group.

Weber et al. [18] employed a standardized 20-item QoL questionnaire based on the EORTC QoL questionnaire in their study of 101 patients with HNC who received surgery and/or RT or CCRT (H&N35). MMOs were assessed in this investigation using the Therabite® motion scale; according to the cut-off set in the Dijkstra et al. study, an MMO of less than 35 mm was termed trismus. Both MMO measurements and survey results demonstrated that patients with oral and pharyngeal cancers had eating (65%) and drinking (70%) problems owing to decreased mouth opening. Although the study's findings have a significant impact on the literature, one of its limitations is that patients with a mouth opening of 15 mm and one patient with a mouth opening of 35 mm were not fully specified, and patients with a mouth opening of less than 36 mm were assessed generally [18].

Thomas et al. [30] employed another RIT assessment technique in 150 patients with oropharyngeal cancer treated solely with RT. Patients were classified into three categories based on the severity of RIT using this system: Mild: MMO > 30 mm; moderate: MMO between 15–30 mm; severe: MMO < 15 mm. While such a rating system is more instructive for revealing how RIT affects patients' daily activities and QoL, it cannot be fully representative of all groups unless it is accompanied by a QoL questionnaire survey focused on assessing their health-related issues. The main advantage of this research over others is that it split the patients into groups, making the impact of RIT more visible and revealing the individual features of each trismus group.

In another study, Jen et al. [31] evaluated the prevalence of RT in relation to the dose of RT in 222 patients diagnosed with nasopharyngeal cancer. The patients were separated into two groups in this investigation: those who had RT in either twice-daily or once-daily fractions. An MMO of 20 mm was deemed trismus, with its prevalence being determined as a function of the RT fractionation scheme. Nonetheless, the study's < 20 mm trismus cutoff is not generally used for HNC patients. This classification, which sets the cutoff value at 20 mm, leaves out patients in the trismus group who are above this cutoff value but below the normal mouth-opening limit and does not offer a thorough categorization of trismus occurrence rate. With such an approach, it may be challenging to establish the actual consequences of this complication since it is unclear at what dose and fractionation level the mouth opening falls below pretreatment levels.

Thirty-nine HNC patients who received definitive RT were the subjects of an investigation by Nyguen and colleagues representing the first of its kind research in such patient groups [32]. The MMOs of these patients was defined as trismus if it was 40 mm or less, and RIT appeared in 30% of those who met this MMO cutoff. Dijkstra [11] modified the typical MMO values established between 40 and 50 mm for the group of healthy patients [33] to 36 mm for HNC patients. In this situation, it is unclear whether we should logically assess people with MMO between 36 mm and 40 mm in the trismus or the non-trismus group. As a result, this situation might affect the therapies given to patients following RT and might make patients less attentive to any necessary precautions. On the other hand, Buchbinder et al. [34], on the other hand, established 30 mm as the cutoff value of MMO in their analysis of 21 post-RT trismus patients diagnosed with oral cancer and separated the entire study population into two batches: trismus and non-trismus. The rate and severity of trismus, however, cannot be precisely assessed in this study because the pre-RT MMOs of these patients are unknown. Like Dijkstra et al. [11], Agarwal and colleagues utilized the MMO cutoff value of 35 mm and examined 30 study participants for RIT [35,36]. If the cutoff is exact, this strategy should theoretically cover all patients with trismus. However, individuals with MMO > 35 mm will be regarded as healthy regardless of the decline in the affected individual's objective functioning and QoL status as opposed to pre-RT measurements. Such a definition will undoubtedly impact the prevalence of RIT and underestimate the severity of the sequela in an artificial manner.

4. DISCUSSION

Trismus, or lockjaw, is typically caused by an ongoing tetanic spasm of the masticatory muscles. Trismus is a significant cause of morbidity in HNC patients receiving RT or CCRT. Additionally, due to weight loss brought on by inadequate nutrition, trismus may result in low tumor control rates and higher rates of cancer-related mortality in these patient groups. Although initially used to describe reduced mouth opening brought on by tetanus, it now refers to reduced mouth opening brought on by a broad range of etiologies, including the RT and CCRT [36]. Trismus is divided into subgroups based on

Table 1. Pros and cons of the various definitions of radiation-induced trismus

Author/Year	Definition	Pros	Cons
Nyguen et al. [32]	• < 40 mm trismus	• One -step MMO measurement	• Increased prevalence of trismus due to high cut-off value • Didn't use a QoL survey • No Grading • Not determine the limitation of jaw mobility • Inadequate to emphasize the severity of trismus • Not Determine the limitation of jaw daily activity
Thomas et al. [30]	• MMO > 30 mm Mild • MMO between 15–30 mm moderate • MMO < 15 mm severe	• Grading • Categorization • Emphasize the severity of trismus	• MMO's upper limit for trismus is unclear • Didn't use a QoL survey • Not Determine the limitation of jaw daily activity • Not determine the limitation of jaw mobility
Bucbinder, et al. (1993)	• ≤ 30 mm trismus	• One -step MMO measurement	• Didn't Use a QoL survey • No Grading • Not determine the limitation of jaw mobility • Inadequate to emphasize the severity of trismus • Not Determine the limitation of jaw daily activity
Goldstein, et al. [39]	• C-1; > 40 mm MMO- normal • C-2; 30-39 mm MMO - trismus • C-3; 0- 29 mm MMO - trismus	• Categorization • Grading • Determination of limitation of jaw mobility	• Inadequate to emphasize the severity of trismus • Didn't use a QoL survey
Jen, et al. [31]	• < 20 mm trismus	• One -step MMO measurement	• Decreased prevalence of trismus due to low cut-off value • Didn't use a QoL survey • No Grading • Not determine the limitation of jaw mobility • Inadequate to emphasize the severity of trismus • Not Determine the limitation of jaw daily activity
Ozyar, et al. [26]	• < 30mm trismus	• One -step MMO measurement	• Didn't use a QoL survey • No Grading • Not determine the limitation of jaw mobility

Author/Year	Definition	Pros	Cons
			• Inadequate to emphasize the severity of trismus • No Determine the limitation of jaw daily activity
Dijkstra, et al. [11]	• ≤ 35 mm trismus	• One step measuring of MMO	• Didn't use a QoL survey • No Grading • Not determine the limitation of jaw mobility • Inadequate to emphasize the severity of trismus
Scott, et al. [42]	• ≤ 35mm trismus Grading MMO; • 20-24 mm • 25-29 mm • 30-34 mm • 35-39 mm • 40-44 mm • 45mm +	• Uses a QoL survey • Emphasize the severity of trismus • Grading • Determination of limitation of jaw mobility • Determination of limitation of jaw daily activity	• 0-19 mm MMO undefined
Barañano, et al. [45]	• 20-35 mm trismus	• Limiting MMO to determine trismus • One -step MMO measurement	• MMO <20mm undefined • Didn't use a QoL survey • Not determine the limitation of jaw mobility • Inadequate to emphasize the severity of trismus • Not Determine the limitation of jaw daily activity
Pauli, et al. [44]	• ≤ 35 mm trismus	• One -step MMO measurement	• Didn't use a QoL survey • No Grading • Not determine the limitation of jaw mobility • Inadequate to emphasize the severity of trismus • Not Determine the limitation of jaw daily activity
Loorents, et al. [41]	• < 35mm trismus	• Uses a QoL survey • Emphasize the severity of trismus • Determination of limitation of jaw mobility • Determination of limitation of jaw daily activity • One -step MMO measurement	• No Grading
Lindblom, et al. [24]	• ≤ 35 mm trismus	• Uses a QoL survey	• No grading

Author/Year	Definition	Pros	Cons
		• Emphasize the severity of trismus • One -step MMO measurement • Determination of pain and limitation of jaw daily activity	
Steiner, et al. [25]	• < 35 mm trismus • < 25 mm severe trismus	• Grading • Determination of limitation of jaw daily activity and jaw mobility • Emphasize the severity of trismus	• 25 mm < MMO <35mm undefined • Didn't use a QoL survey

Abbreviations: *MMO; maximum mouth opening, mm; millimeter**,** QoL; quality-of life, C; category*

the principal anatomic site involved or the specific cause. Hence, while some specialists classify trismus based on intra- and extra-articular TMJ involvement [37], others rely on the etiology and use a comprehensive list of trismus categorizations that include infectious, traumatic, neurogenic, neoplastic, radiation-related, and many more [38].

The typical range of mouth opening is 40 to 60 mm (two to three finger breadths). Many experts believe that an MMO of less than 35 mm is trismus for cancer patients [38], although there may not be a one-size-fits-all solution. In the literature, there are numerous definitions and categorizations of trismus (Table 1). For example, when evaluating the incidence of RIT in 21 patients with nasopharyngeal cancer, Goldstein et al. classified the MMO into three categories: greater than 40 mm (normal), 30–39 mm, and 0-29 mm [39]. According to the authors, a normal mouth opening is any MMO that is 40 mm or larger. The concept of trismus was made more reliable by the addition of MMO measurements taken during lateral and protrusive movements of the jaws. Following these additional measures, a mouth opening of more than 7 mm during lateral and protrusive motions was categorized as normal; 4-6 mm as category 2 (trismus); and 0-3 mm as category 3 (severe trismus). The motion categories in both the lateral and protrusive MMOs were combined to create the mobility index. Due to the measurement of MMO during functional movements, this definition of compound trismus more clearly demonstrates the exact magnitude of the restriction of jaw mobility. However, some patients (MMO = 35–39 mm) who Goldstein et al. classified as having trismus were given normal scores in the widely cited paper by Dijkstra et al. [11], creating a definitional inconsistency. Lindblom et al. [24] also employed a cutoff value of 35 mm for trismus diagnosis. The authors stressed the need of using a same cutoff measure for RIT classification across studies by pointing out that if they used 20 mm as the cutoff value, only 8% of their patients rather than the stated 43% would be categorized as having trismus. Trismus was defined by Steiner et al. [40] using an MMO cutoff of 35 mm, with an MMO of less than 25 mm indicating severe trismus. The authors did not, regrettably, consider the MMOs between 25 and 35 mm to have clinical significance in terms of the severity of trismus. Compared to Dijkstra's straightforward definition [11], this classification helps evaluate trismus and emphasize its severity; however, it is constrained in its ability to reveal the restriction of jaw movements because the amount of mouth opening determined does not match the data from Goldstein and colleagues' research [39]. Furthermore, patients with MMOs of less than 20 mm are not classified, which makes it impossible to assess these patients. Thus, due to the exclusion of the group most adversely affected by RT in terms of trismus, the prevalence and importance of RIT were overestimated.

With a cutoff value for MMO between 30 and 40 mm, RIT is defined differently by various experts. Dijkstra et al. [11], who determined that an MMO of 35 mm or less in HNC patients qualifies as trismus, provided the most widely acknowledged classification of trismus. The most widely accepted classification of trismus is the study by Dijkstra et al, who considered an MMO of 35 mm or less in HNC patients to be trismus. Loorents et al. [41]. and Scott et al. [42]. selected an MMO cutoff value < 35 mm for trismus definition in their studies. Additionally, the authors employed three different questionnaires, namely the University of Washington Quality of Life Scale (UWQOL) v4, the Liverpool Oral Rehabilitation Questionnaire (LORQ), and the performance status scale to illustrate the impact of this serious complication on patients QoL measures. Furthermore, the patients' MMOs were sorted into groups ranging from 20 mm to 45 mm at 4 mm intervals. Questionnaires were utilized to examine the clinic-patient connection and to discriminate between patients based on MMO, lack of chewing, the fullness of meals, and overall satisfaction with life. Nevertheless, failing to include patients with MMOs between 0 and 19 mm in this definition system may cause patients in the severe trismus stage to go unnoticed and prevent evaluation of their clinical picture.

Because Dijkstra et al. did not apply a graded definition when identifying patients as having trismus based on the 35-mm cutoff value, patients with 20-mm and 34-mm MMO were examined in the same condition, and the severity of this complication was not assessed individually for two patients [11]. By adding QoL surveys to this cutoff value, Loorents et al. [41], although they did not use a graded classification, allowed the degree to which patients were at risk to be assessed at RIT according to the extent of MMO. In this study, a 5.2% decrease was observed at 6^{th}. week of post-RT period MMOs compared with baseline measurements in the untreated control group. As a result, a

straightforward RIT classification might not accurately depict the effects of trismus with different MMO restriction severity levels. Furthermore, a sizable portion of patients may have their diagnosis missed by ungraded classification methods. Dijkstra's reported specificity (true negative) rate of 71% [11], for instance, indicates that there is a 29% chance of misdiagnosing trismus in patients who do not have it.

The cutoff value for trismus was set at 30 mm by Ozyar et al. [26] and Buchbinder et al. [43], but they did not employ a grading system. However, using a cutoff value of 35 mm will demonstrate that patients in the group who have a normal mouth opening of 31–34 mm, as per Ozyar et al. [26] and Buchbinder et al. [43], have trismus as per the definitions of Dijkstra et al. [11] and Pauli et al. [44]. Unfortunately, due to the wide variations in RIT frequency across reference studies, the findings of the available investigations may not accurately reflect the prevalence of this debilitating complication of RT in patients at risk. Scientifically, these huge discrepancies make it difficult to make valid comparisons between the results of the available studies and the impacts of RIT on the affected patients.

Another classification for trismus is the one used by Baraano et al. [45], which refers to an MMO of 20–35 mm. Studies like those of Dijkstra et al. that used a 35 mm cutoff are typically viewed as inferior to this classification [11]. However, because it did not classify MMOs below 20 mm, this classification does not accurately reflect the prevalence of RIT. As opposed to studies with a single cutoff point, Thomas et al. classified trismus according to its severity, and this seems to be more steadfast in determining the incidence of RIT and the impact of RIT on patients' daily lives [30]. Sadly, due to the lack of a set upper limit for MMOs for trismus, it may be challenging to estimate the incidence rate of MMOs up to 40–60 mm by classifying them into the mild trismus group.

Beyond the trismus cutoffs mentioned above, Jen et al. [31] and Nyguen et al. [32], respectively, proposed two additional cutoffs for the RIT definition. In their study assessing the prevalence of RIT in patients with nasopharyngeal carcinoma, Jen et al. accepted the MMO threshold of 20 mm for trismus [31]. The prevalence of RIT may have decreased due to the authors' low threshold and acceptance of MMOs greater than 20 mm as normal mouth opening, leaving these patients unnoticed. The RIT rate might have been 5% instead of 17% in these patients if the cutoff value of 35 mm used by Dijkstra et al. [11] had been applied. Similarly, in a study of 39 patients presented by Nyguen et al., the incidence of RIT was calculated as 30% in patients treated with RT alone, with a cutoff value of 40 mm for trismus [32]. The incidence determined at 30% would have been much higher if cutoff values such as 35 mm, 30 mm, or 20 mm—frequently used by other researchers to determine trismus—had been used instead of this value. The planning for the prevention and treatment of RIT, which may have a significant positive impact on this patient group's QoL, may be misperceived as less critical, given the dissimilarities in prevalence rates.

The uncertainty in the multiple MMO values indicated above for trismus is due to the fact that a frequently used value has not yet been defined, and hence the rate of RIT fluctuates. In this respect, it may not be the best technique to assess RIT only on the decrease in MMO by employing a single cutoff criterion. Patients' daily activities, such as eating, drinking, speaking, chewing, and swallowing, as well as their social and psychological status, are impacted by every millimeter that the MMO shrinks. Staggering MMO to measure trismus severity, in addition to defining a uniform cutoff value, may be another option for determining the frequency of RIT and the real burden of this complication on patients. Performing MMO only based on measuring the interincisal gap and without evaluating the degree of MMO during lateral and protrusive mandibular motions may impede the exact decline of MMO and may not accurately represent the impact of this decrease on jaw functions and mobility. The inclusion of QoL surveys in studies, in addition to all of these measurements and evaluations, may aid in the development of new cutoffs for trismus assessment.

5. CONCLUSION

Despite its well-known adverse impacts on the affected individual's QoL measures, it appears that there is currently no irrefutable and commonly accepted MMO threshold for trismus when all of these studies and comparisons are taken into account. As a result, a unique, precise, and widely recognized MMO cutoff value for trismus definition is urgently required, possibly one that includes interincisal measures as well

as mandibular protrusive and lateral MMO measurements. Furthermore, identification of a unified categorization that classifies trismus based on severity (likely a percentage change in MMO) and is supported by QoL survey results is of critical importance. Only by objectively and thoroughly establishing the prevalence of RIT and its influence on many aspects of a patient's QoL and functioning can we create the most effective preventative and therapeutic methods to enhance patients' QoL and avoid or lessen this unpleasant RT complication. Future studies addressing these issues will provide vital information and direction for implementing preventative and therapeutic strategies in treatment and follow-up algorithms for such patients.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ferlay J, Soerjomataram I, Ervik M. Cancer incidence and mortality worldwide: IARC Cancer Base No. 11. International Agency for Research on Cancer Globocan. 2012;1.0. Available:http://gco. iarc.fr/today/home Accessed July 24, 2018.
2. Nahavandipour A, Jakobsen KK, Gronhoj C, et al. Incidence and survival of laryngeal cancer in Denmark: a nation-wide study from 1980 to 2014. Acta Oncol. 2019;58(7):977–982.
3. Shiboski CH, Schmidt BL, Jordan RC. Tongue and tonsil carcinoma increasing trends in the U S population ages 20–44 years. Cancer. 2005;103(9): 1843–1849.
4. Sturgis EM, Cinciripini PM. Trends in head and neck cancer incidence in relation to smoking prevalence: an emerging epidemic of human papillomavirus-associated cancers? Cancer. 2007; 110(7):1429–1435.
5. Liu C, Liao L, Wu G, et al. Radiation-induced second primary squamous cell carcinoma of the oral cavity after radiotherapy for nasopharyngeal carcinoma. Oral Oncol. 2020;109:104863.
6. Jahreiss MC, Heemsbergen WD, van Santvoort B, et al. Impact of advanced radiotherapy on second primary cancer risk in prostate cancer survivors: a nationwide cohort study. Front Oncol. 2021;11:771956
7. Jin MC, Qian ZJ, Megwalu UC. Risk of second primary malignancies after external beam radiotherapy for thyroid cancer. Anticancer Res. 2022;42(3):1359–1365.
8. Strojan P, Hutcheson KA, Eisbruch A, Beitler JJ, Langendijk JA, Lee AWM, Corry J, Mendenhall WM, Smee R, Rinaldo A, Ferlito A. Treatment of late sequelae after radiotherapy for head and neck cancer. Cancer Treat Rev. 2017;59:79-92.
9. Cohen E, LaMonte S, Erb N, et al. American cancer society head and neck cancer survivorship care guideline. CA Cancer J Clin. 2016;66:204-239.
10. Somay E, Yilmaz B, Kucuk A, Pehlivan B, Selek U, Topkan E. Impact of radiation-induced trismus on patients' life quality. Archives of Current Research International. 2022;22;12-24.
11. Dijkstra PU, Huisman PM, Roodenburg JL. Criteria for trismus in head and neck oncology. Int J Oral Maxillofac Surg. 2006;35:337–342.
12. Gallagher C, Gallagher V, Whelton H, Cronin M. The normal range of mouth opening in an Irish population. J Oral Rehabil. 2003;30:1–7.
13. Boozer CH, Ferraro EF, Weinberg R. The effects of age, race and sex on the interincisal measurement. Ann Dent. 1984;43:5.
14. Cauduro Da Rosa G, Fernandes MM, Crosato EM, Nogueira de Oliveira R. Proposal of a formula mouth opening reduction assessment, for forensic purposes. J Forensic Odontostomatol. 2021;1(39):2-8.
15. Yen CI, Mao SH, Chen CH, Chen CT, Lee MY. The correlation between surface electromyography and bite force of mastication muscles in Asian young adults. Ann Plast Surg. 2015;74 (Suppl 2):S168-72.
16. Carlsson GE, Svardstrom G: A survey of the symptomatology of a series of 299

patients with stomatognathic dysfunction. Swed Dent J. 1971;64:889.
17. Agerberg G: On mandibular dysfunction and mobility. Umea University Odontological Dissertations, Umea Sweden. 1974;(abstr 3).
18. Weber C, Dommerich S, Pau HW, Kramp B. Limited mouth opening after primary therapy of head and neck cancer. Oral Maxillofac Surg. 2010;14:169–173.
19. Louise Kent M, Brennan MT, Noll JL, Fox PC, Burri SH, Hunter JC, Lockhart PB. Radiation-induced trismus in head and neck cancer patients. Support Care Cancer. 2008;16:305–309.
20. Van Cann EM, Dom M, Koole R, Merkx MA, Stoelinga PJ. Health related quality of life after mandibular resection for oral and oropharyngeal squamous cell carcinoma. Oral Oncol. 2005;41:687–693.
21. Bensadoun RJ, Riesenbeck D, Lockhart PB, Elting LS, Spijkervet FK, Brennan MT, Trismus Section, Oral Care Study Group, Multinational Association for Supportive Care in Cancer (MASCC)/International Society of Oral Oncology (ISOO). A systematic review of trismus induced by cancer therapies in head and neck cancer patients. Support Care Cancer. 2010;18: 1033–1038.
22. Melchers LJ, Van Weert E, Beurskens CHG, Reintsema H, Slagter AP, Roodenburg JLN, Dijkstra PU. Exercise adherence in patients with trismus due to head and neck oncology: A qualitative study into the use of the Therabite®. Int J Oral Maxillofac Surg. 2009;38: 947–954.
23. LENT SOMA tables. Radiother Oncol. 1995;35(1):17-60.
24. Lindblom U, Garskog O, Kjellen E, Laurell G, Levring Jaghagen E, Wahlberg P, Zackrisson B, Nilsson P. Radiation-induced trismus in the ARTSCAN head and neck trial. Acta Oncol 2014;53: 620–627.
25. Steiner F, Evans J, Marsh R, Rigby P, James S, Sutherland K, Wickens R, Nedev N, Kelly B, Tan ST. Mouth opening and trismus in patients undergoing curative treatment for head and neck cancer. Int J Oral Maxillofac Surg. 2015;44:292–296.
26. Ozyar E, Cengiz M, Gurkaynak M, Atahan IL. Trismus as a presenting symptom in nasopharyngeal carcinoma. Radiother Oncol. 2005;77:73–76.
27. Kamstra JI, Dijkstra PU, van Leeuwen M, Roodenburg JL, Langendijk JA. Mouth opening in patients irradiated for head and neck cancer: A prospective repeated measures study. Oral Oncol 2015;51:548–555.
28. Wetzels JW, Merkx MA, de Haan AF, Koole R, Speksnijder CM. Maximum mouth opening and trismus in 143 patients treated for oral cancer: a 1-year prospective study. Head Neck. 2014;36: 1754–1762.
29. Gebre-Medhin M, Haghanegi M, Robert L, Kjellen E, Nilsson P. Dose-volume analysis of radiation-induced trismus in head and neck cancer patients. Acta Oncol. 2016; 55:1313–1317.
30. Thomas F, Ozanne F, Mamelle G, Wibault P, Eschwege F. Radiotherapy alone for oropharyngeal carcinomas: the role of fraction size (2 Gy vs 2.5 Gy) on local control and early and late complications. Int J Radiat Oncol Biol Phys. 1988; 15(5):1097-102
31. Jen YM, Lin YS, Su WF, Hsu WL, Hwang JM, Chao HL, Liu DW, Chen CM, Lin HY, Wu CJ, Chang LP, Shueng PW. Dose escalation using twice-daily radiotherapy for nasopharyngeal carcinoma: Does heavier dosing result in a happier ending? Int J Radiat Oncol Biol Phys. 2002; 54(1):14-22.
32. Nguyen TD, Panis X, Froissart D, Legros M, Coninx P, Loirette M. Analysis of late complications after rapid hyper fractionated radiotherapy in advanced head and neck cancers. Int J Radiat Oncol Biol Phys. 1988;14(1):23-25.
33. Zawawi KH, Al-Badawi EA, Lobo SL, Melis M, Mehta NR. An index for the measurement of normal maximum mouth opening. Journal-Canadian Dental Association. 2003;69(11):737-741.
34. Buchbinder D, Currivan RB, Kaplan AJ, Urken ML. Mobilization regimens for the prevention of jaw hypomobility in the radiated patient: a comparison of three techniques. J Oral Maxillofac Surg. 1993; 51(8):863-867.
35. Agarwal P, Shiva Kumar HR, Rai KK. Trismus in oral cancer patients undergoing surgery and radiotherapy. J Oral Biol Craniofac Res. 2016;6(Suppl 1):S9-S13.
36. Santiago-Rosado LM, Lewison CS. Trismus. [Updated 2021 Nov 24]. In: Stat Pearls [Internet]. Treasure Island (FL): Stat Pearls Publishing; 2022. Available:https://www.ncbi.nlm.nih.gov/books/NBK493203/

37. Tveteråas K, Kristensen S. The aetiology and pathogenesis of trismus. Clin Otolaryngol Allied Sci. 1986;11(5):383-387.
38. Dhanrajani PJ, Jonaidel O. Trismus: aetiology, differential diagnosis and treatment. Dent Update. 2002;29(2): 88-92, 94
39. Goldstein M, Maxymiw WG, Cummings BJ, Wood RE. The effects of antitumor irradiation on mandibular opening and mobility: a prospective study of 58 patients. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1999;88(3):365-373.
40. Steiner F, Evans J, Marsh R, Rigby P, James S, Sutherland K, Wickens R, Nedev N, Kelly B, Tan ST. Mouth opening and trismus in patients undergoing curative treatment for head and neck cancer. Int J Oral Maxillofac Surg. 2015;44:292–296.
41. Loorents V, Rosell J, Karlsson C, Lidbäck M, Hultman K, Börjeson S. Prophylactic training for the prevention of radiotherapy-induced trismus - a randomised study. Acta Oncol. 2014;53(4):530-538.
42. Scott B, Butterworth C, Lowe D, Rogers SN. Factors associated with restricted mouth opening and its relationship to health-related quality of life in patients attending a Maxillofacial Oncology clinic. Oral Oncol. 2008;44(5): 430-438.
43. Buchbinder D, Currivan RB, Kaplan AJ, Urken ML. Mobilization regimens for the prevention of jaw hypomobility in the radiated patient: a comparison of three techniques. J Oral Maxillofac Surg. 1993; 51:863–867.
44. Pauli N, Fagerberg–Mohlin B, Andrell P, Finizia C. Exercise intervention for the treatment of trismus in head and neck cancer. Acta Oncol. 2014;53: 502–509.
45. Barañano CF, Rosenthal EL, Morgan BA, McColloch NL, Magnuson JS. Dynasplint for the management of trismus after treatment of upper aerodigestive tract cancer: A retrospective study. Ear Nose Throat J. 2011;90(12):584-590.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/92411