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ORIGINAL ARTICLE

The impact of the new scene drug "crystal meth" on oral health: a case–control study

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Abstract
Objective The use of methamphetamine (MA), a highly addictive stimulant, is rapidly increasing, with MA being widely abused as the scene drug "Crystal Meth" (CM). CM has been associated with severe oral health effects, resulting in so-called "Meth mouth". This term appeared for the first time in 2005 in the literature and describes the final complex of symptoms including rampant caries, periodontal diseases and excessive tooth wear. The aim of this study was to investigate the effects of chronic CM abuse on teeth and intraoral tissue with respect to potential symptoms of Meth mouth.
Materials and methods In cooperation with two centres for addiction medicine, we performed clinical intraoral investigations in 100 chronic CM users and 100 matched-pair controls. We undertook a caries and periodontal examination by using the clinical parameters DMF-T/DMF-S, bleeding on probing index (BOP) and periodontal screening index (PSI) and tested individual oral hygiene by using approximal space plaque index (API). All clinical data were analysed by the *t* test for independent samples.
Results We found significantly larger numbers of caries ($p < 0.001$) and higher levels of gingival bleeding ($p < 0.001$) and periodontal disease ($p < 0.001$) among CM users. Oral hygiene was significantly lower in CM users ($p < 0.024$).
Conclusion Chronic CM use can lead to extensive potential damage within the intraoral cavity. When CM is used over a long period of time and in the absence of treatment, clinical symptoms in terms of Meth mouth syndrome cannot be excluded.
Clinical relevance Based on our results, we recommend a specific prevention and therapeutic concept including educational campaigns for MA users and specialized dental care for CM patients.

Keywords Crystal methamphetamine · Meth mouth · Caries · Periodontal diseases · Oral hygiene · Prevalence study

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Introduction

Methamphetamine (MA) is a highly addictive stimulant of long historical origin. The substance was first synthesized in Japan 1893 [1] and crystallized in its pure form in 1919 [2]. Because of its disinhibiting and vigilance-increasing effect, MA evoked great political and military interest. Particularly, during the Second World War, the MA-derivative substance "Pervitin" was given to soldiers to increase their self-confidence and risk taking. Currently, the prevalence of MA is estimated at 35 million people worldwide [3] and is a serious problem in many countries [4, 5]. Although MA use appears to be less extensive in Europe than in the USA, the substance is also widespread in many European countries, particularly in the Czech Republic and its bordering countries [5]. The police noted a CM increase of almost 200 % in German border areas to the Czech Republic in a 2-year comparison from 2010 to 2012 [6]. The use of CM leads to euphoria, performance enhancement and increased self-

confidence. These effects are caused by the stimulation of noradrenaline and, in particular, of dopamine receptors. MA inhibits the reuptake of dopamine into the brain vesicles and prolongs its effect in the synaptic cleft [5, 7]. The increased dopamine levels provide the strong physical and psychological stimulation experienced by MA users.

Chronic use of MA can lead to various health problems including cardiovascular diseases, structural brain damage or psychological changes [3, 8]. Recently, however, MA has been associated with severe effects particularly in oral health, including rampant caries and periodontal diseases [3, 8–10]. The term "Meth mouth" appeared in the professional literature for the first time in 2005 [10]. From then on, many authors have demonstrated the probability of Meth mouth after chronic MA or CM use [4, 11, 12]. However, in the current literature, Meth mouth is primarily described on the basis of individual case reports, with a lack of conclusive relationships between chronic MA/CM use and pathogen effects within the intraoral cavity [4, 13, 14]. Systematic study designs in this field are rare, mostly because of difficulties in gaining access to a large number of MA/CM users, the absence of connections between addiction medicine and the dental community and the high demands placed on professionals undertaking clinical examinations.

The aim of this study was to evaluate whether chronic CM abuse increases the risk of caries decay and periodontal diseases significantly and might lead finally to the Meth mouth phenomenon described in the current literature. Therefore, we have established a cooperation between specialist institutions for oral and maxillofacial medicine and addiction medicine in order to conduct systematic clinical intraoral examinations involving international standardized indices in a suitable number of CM users and in a matched-pair control group.

Materials and methods

Study design

This cross-sectional study design involved cooperation between two specialist clinics for addiction medicine in Bayreuth and Hochstadt/Main, Germany, the Department of Oral and Maxillofacial Surgery of the Munich University of Technology, Germany and the Institute for Medical Biometry, Epidemiology and Medical Informatics of the University of Saarland, Germany. With the close consultation of each participating institution, the examining scheme and number of participants were established in advance of the start of the study. In order to provide the study with adequate statistical power, the number of CM users was set at 100. For the optimal comparability of data and verification of our study methods, we recruited a control group including 100 matched-pair control participants, one for each MA user. All study participants were provided with an information document setting out the objectives, risks and benefits of the study. According to the requirements of the ethics committee, we informed each participant about data use and data protection and obtained his or her written consent with regard to participation in the study. Subsequently, each potential study participant could decide independently whether he or she wanted to join the study. Our methods were approved by the local ethics committee of the Munich University of Technology and were in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Participants

The selection and data acquisition of the 100 CM users took place at the addiction clinics at fixed examination appointments over 6-week periods on average in 2012 and 2013. At each examination appointment, 10 CM users on average were examined in a specially prepared separate room with a quiet atmosphere. The necessary equipment for the clinical examination was provided by the Department of Oral and Maxillofacial Surgery of the Munich University of Technology and brought to each examination appointment by the examiners, namely a dentist and a maxillofacial surgeon. Before the beginning of each examination, the executive psychotherapist in each addiction clinic checked the eligibility criteria for the CM group in a short patient interview. Eligibility criteria for the CM group included the constant CM use of 1 g/week beyond a minimum period of 12 months without any withdrawal periods. All participants of the CM group had undergone withdrawal therapy at their examination appointment. However, exclusion criteria were defined as the last CM use of longer than 1 month previously. For the control group, we defined the matched-pair criteria gender and age (+/−1a). Participants for the matched-pair group were randomly selected from hospitalized patients at the University Hospital in Munich and from patients of two ambulatory dental surgeries in Munich and Augsburg, Germany. The selection and examination of the control group were performed by the same dentist and maxillofacial surgeon who performed the examination of the CM group. The examination appointments of the control group took place subsequent to and promptly after each examination appointment of the CM group. Analogous to the CM group, the eligibility criteria of patients were first checked, followed by an informative conversation with respect to the study. If the patient gave written consent, the clinical examination followed.

Data collection

The examination of all participants was divided into three parts. In the first part, caries prevalence was analysed by using the calculation of the DMF-T and DMF-S-indices. In cases of

missing teeth, participants were asked about the precise cause of tooth loss. If tooth loss was not caused by caries or patients did not remember exactly, the missing tooth was not added to the overall index. Active carious lesions per tooth (D-T) and per surface (D-S) were documented separately. Because of the lack of sterilization capacities at the addiction clinics, we used single-use dental instruments (Hager Werken GmbH, Duisburg/Germany) for examining the caries prevalence within the CM group. In the second part, we used the bleeding on probing index (BOP) in order to detect potential gingival inflammatory processes. Each tooth was probed mesially and distally, and subsequently, the BOP index was calculated by the number of bleeding spots divided by all measured spots. To detect the need for periodontal treatment and potential loss of attachment including bone resorption, we determined the periodontal screening index (PSI) for both groups [15]. We divided both jaws into sextants, screened every sextant by using a dental probe and noted the highest code value. In the third part, we also tested individual oral hygiene by using specific intraoral plaque-staining tablets (Mira-2-Ton-Tabletts, Hager Werken, Duisburg, Germany) and, subsequently, we calculated the approximal space plaque index (API) [16]. Because plaque evaluation by using the API strongly depends on subjective opinion, all oral hygiene testing was performed by the same examiner for all study participants.

Statistical analyses

We used the software programmes SPSS 21.0. (IBM, Armonk, USA) and Cytel Studio version 10 (Cytel, Cambridge, USA) for the statistical analysis and Microsoft Excel 2010 (Microsoft, Redmond, USA) for data transfer and handling. For all indices, we used the *t* test for independent samples comparing means. The two-sided level of significance was set at $\alpha = 0.05$. Multiple testing was accounted for by applying the procedure of Bonferroni-Holm, i.e. by sorting *p* values from the lowest to the highest and comparison with the local adjusted significance level α/i, where *i* is the order of the respective *p* value p_i. For the graphical depiction of mean values, bar graphs containing the related 95 % confidence intervals were used.

Results

We measured a significantly higher mean value of the DMF-T index in the CM group with 12.3 teeth (SD ± 5.9) compared with the control group with a mean value of 7.2 teeth (SD ± 5.9, $p < 0.001$). The same applied to the DMF-S index with a mean value of 32.5 affected tooth surfaces (SD ± 29.7) for the CM group versus a mean value of 17.9 (SD ± 20.1) for the control group ($p < 0.001$). Likewise, we found significantly more acute caries lesions within the CM group with a mean value of 3.4 teeth (SD ± 2.9, $p < 0{,}001$) and mean 4.7 surfaces (SD ± 5.2, $p < 0{,}001$), whereas the control group showed mean values of only 0.7 teeth (SD ± 1.4) and 0.9 surfaces (SD ± 2.1) (Table 1). All clinical data are graphically represented in Fig. 1.

With regard to gingival and periodontal diseases, the CM group showed significantly higher gingiva inflammation with a mean BOP of 39.6 % (SD ± 13.5) compared with the control group with 28.4 % (SD ± 19.2, $p < 0.001$). Likewise, the mean PSI index was significantly higher in the CM group with 2.75 (SD ± 0.6) compared with the control group with 2.1 (SD ± 0.86; $p < 0.001$) (Table 1).

Insufficient oral hygiene could be observed in the CM group with a mean API of 55.7 % (SD ± 18.6) and in the control group with a mean API of 48.1 % (SD ± 27). However, the difference between the two groups was significant with more intraoral plaque being found within the CM group ($p = 0.024$) (Table 1).

Discussion

We have found a significantly higher caries, gingivitis and periodontitis prevalence within a group of CM users than within a control group of the same age and sex without CM use. These findings are in agreement with observations of previous studies [3, 4, 8, 14, 17–21].

In the current literature, chronic MA use is often associated with "rampant caries" [3, 9, 22]. However, these severe effects of MA are primarily based on case reports, one of which concerned a 30-year-old American who had 19 rampant carious lesions after chronic MA use for at least 5 years [4] and another involved a 24-year-old man with 19 carious and erosive lesions after chronic MA use over a period of 11 years [14]. We have used the international common indices DMF-T and DMF-S, which have been established to determine the caries prevalence in various population groups [23–28]. Our results show a significantly higher DMF-T and DMF-S index and significantly more active carious lesions with regard to the D-T and D-S indices within the CM group. Therefore, our results show a significantly higher risk for caries in cases of chronic MA use and are in agreement with previous observations. However, we have only found a few cases of typical symptoms of Meth mouth syndrome including rampant caries located at labial and approximal surfaces [3, 22]. Clinical investigations combined with radiography, as used by the authors of the case reports, are more sensitive, and this might explain the large number of carious lesions of these case reports compared with our results.

Not only a high caries risk but also pathogenic effects in the parodontium including gingiva inflammation and parodontitis [11, 17, 19] with subsequent bone loss [29] are described in cases of chronic MA use. With regard to the BOP index and PSI, our results reveal a significantly higher risk for gingivitis

Table 1 Clinical data

		CM group (n = 100)	Control group (n = 100)	p value
Caries prevalence				
DMF-T (n = 28)	Mean (SD)	12.3 (5.9)	7.2 (5.9)	<0.001
DMF-S (n = 128)	Mean (SD)	32.5 (29.7)	17.9 (20)	<0.001
D-T (n = 28)	Mean (SD)	3.4 (2.9)	0.7 (1.4)	<0.001
D-S (n = 128)	Mean (SD)	4.7 (5.2)	0.9 (2.1)	<0.001
Periodontal diseases				
BOP (%)	Mean (SD)	39.6 (13.5)	28.4 (19.2)	<0.001
PSI (min 0–max 4)	Mean (SD)	2.75 (0.6)	2.1 (0.9)	<0.001
Oral hygiene				
API (%)	Mean (SD)	55.7 (18.6)	48.2 (27.2)	0.024

and periodontitis in cases of chronic MA use and confirm previous case reports [4, 22]. In this context, Tipton et al. [29] have found an increased production of the inflammation mediator interleukin (IL)-1-beta under the influence of MA. Furthermore, decreased intraviral activity under the influence of MA in mice [30] and inhibiting effects of MA on receptor-mediated phagocytosis, MHC class antigen II processing and antigen presentation have been observed [31]. Therefore, based on our clinical findings, previous case reports and cellular observations, we assume that the immune-weakening effects of MA result in increased inflammatory processes, which, particularly during chronic MA abuse, will also involve periodontal tissues.

Our results with regard to the significantly higher caries-gingivitis and parodontitis prevalence within the MA group, however, have to be considered in the context of several influencing factors. The individual risk for oral diseases, in particular, the risk of caries, depends on various accompanying factors such as oral hygiene, quantity and quality of saliva, nutrition behaviour, consumption of other substances with pathogenic potential on oral health, socioeconomic backgrounds or dental care.

Oral hygiene including correct and regular dental care plays an important role in preventing tooth decay and periodontal diseases [32]. In the case of chronic MA use, many authors report strong neglect or the complete lack of oral hygiene measures in MA abusers [8, 17, 33]. However, systematic clinical investigations with regard to oral hygiene in MA users are rare. Morio et al. performed a retrospective study with 18 MA users and 18 control subjects and showed an increased caries risk because of marginal dietary and insufficient oral hygiene, but no clinical examinations were carried out [34]. In our study, we have evaluated individual oral hygiene by using API and have found significantly more plaque and, subsequently, poorer oral hygiene in the MA group. Particularly, in combination with high sugar intake, which is considered to be a relevant reason for rapid tooth decay during periods of MA abuse [8, 35], the risk for caries can increase strongly. However, we should mention that oral hygiene examination by using API strongly depends on the examiner's subjective opinion with regard to positive plaque points. Furthermore, oral hygiene measures such as teeth brushing shortly before the examination can alter the representative amount of plaque. Hence, in this context, we recommend multiple API examinations at regular intervals combined with statements regarding individual oral hygiene measures and nutrition behaviour, particularly, sugar intake, in order to assess caries risk.

A massive decline of saliva production or even xerostomia is considered to play a crucial role in MA-associated tooth decay [11] or even Meth mouth[9, 21]. Xerostomia leads to a loss of the important protective properties of saliva such as the neutralization of plaque-induced acids and the remineralization of dental enamel and, therefore, xerostomia substantially increases the risk of caries [36]. The sympathomimetic central stimulation of MA on the salivary-inhibiting alpha-2-receptors in the brain seems to be the most likely reason for this effect [22]. Another explanation has been shown by Okuba et al. who induced MA-withdrawal stress in rats and found a specific pathway activation in salivary glands, resulting in the inhibition of salivary secretion [37]. Furthermore, the MA-induced dehydration caused by the increased physical activity during an excessive period of MA use might reduce saliva production significantly [20, 22]. Additionally, under the influence of MA, a decrease of the salivary pH and, subsequently, a decrease of the buffer capacity of saliva have been postulated [12, 38]. An acidic pH value of saliva combined with decreased salivary flow rates and decreased salivary buffer capacity offers a high potential for dental erosion [39]. Thus, during chronic MA abuse, not only does the risk for caries increase because of xerostomia but also the risk for dental erosion is elevated because of decreased buffer capacity. Both factors in combination might trigger extensive tooth decay.

Not only MA but also other illegal drugs such as cannabis, sedatives, stimulants or hallucinogens have a high damaging

potential on oral health. For example, Darling et al. have found a higher risk for caries and xerostomia in cannabis abusers [40]. Xerostomia can also be triggered by long-term opioid consumption [41] or tranquilizers such as benzodiazepine [42]. Increased gingival lesions and dental erosions are considered an effect of cocaine [43]. In cases of chronic MA abuse, a collateral consumption of the aforementioned illegal drugs is not rare [4]. Thus, we cannot exclude that oral health hazards in MA abusers are also triggered by this collateral consumption. This assumption is corroborated by the results of Cretzmeyer et al. who performed a dental examination of a total of 31 hospitalized patients and showed dental diseases in both groups with no differences between MA users and users of other addictive substances [44]; however, only a small sample size was studied. Additionally, no cases have been described for other substances with comparable drastic consequences on oral health such as those seen in MA users. Nevertheless, the collateral consumption of other drugs probably triggers MA-associated severe effects on oral health and should be kept in mind during studies of MA users.

Finally, with regard to the previously described Meth mouth in the USA, the country in which most Meth mouth observations have been made, socially weak people have limited access to adequate health services in the event of sickness, because of the lack of a social service and health insurance system. Research results and empirical data show that the incidence of caries increases in the event of decreased socioeconomic status and homelessness and that, in cases of a lack of access to health care, these problems lead to poor oral health [45]. In Germany, on the contrary, therapeutic measures are provided, even in cases of socially weak status, because of the provision of a public health care system and a statutory health insurance. Therefore, poorer dental care might be expected in US-American MA users in whom untreated massive caries formation over several years can lead to the typical clinical images of Meth mouth.

The following points have to be considered critically with respect to this study. With regard to the clinical data collection, X-rays were not taken because of ethical, logistic and financial reasons; this would however have increased the diagnostic sensitivity of the DMF-T index, especially in the approximate surface. Furthermore, the CM users examined were undertaking withdrawal and cessation therapy in a hospital at the time of examination and were thus not in an acute phase of use. The cross-section concept with a single period of data collection should ideally be extended by a longitudinal study during which chronic MA users are examined for a long period of time.

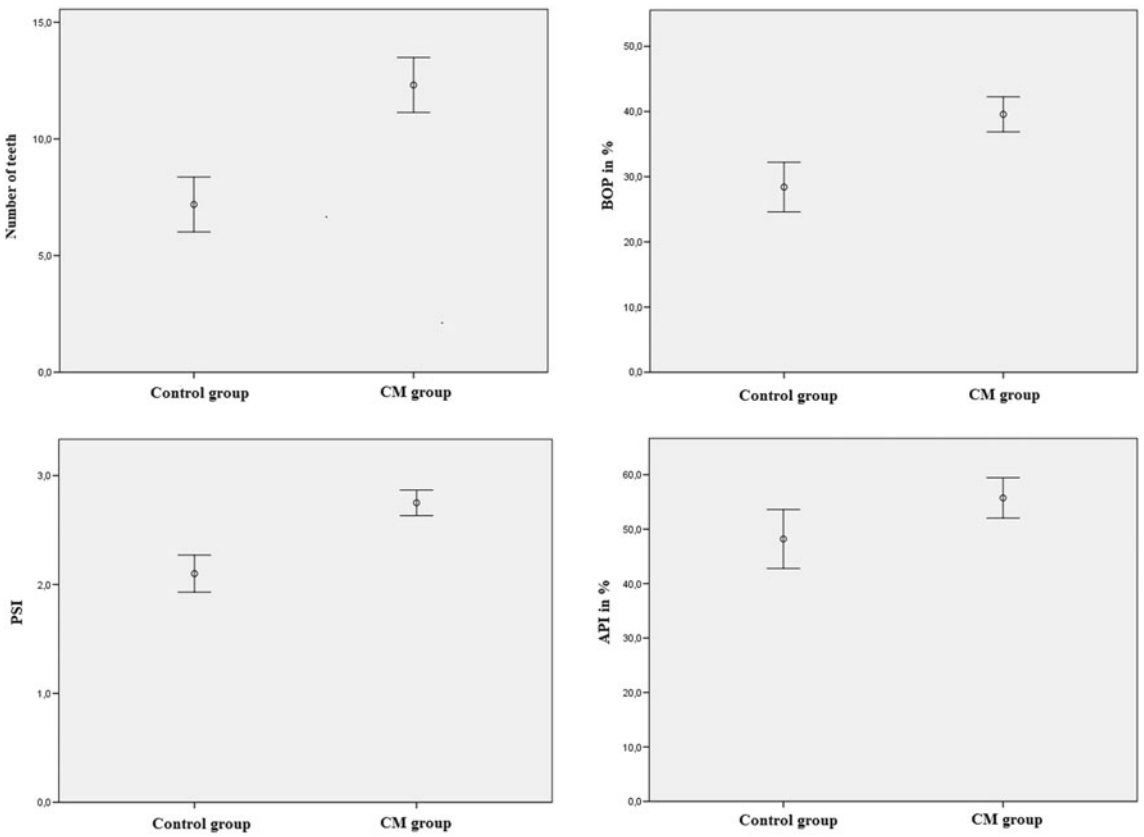

Fig. 1 Mean values of DMF-T index ($p < 0.001$), BOP index ($p < 0.001$), PSI ($p < 0.001$) and API ($p = 0.024$) of both groups

Conclusion

Chronic MA use has a high damaging potential for the stomatognathic system. Thus, the direct consequences of the use of this substance use including xerostomia, bruxism, decreased saliva buffer capacity and many accompanying risk factors such as the extensive consumption of other toxic substances, lack of dental care and socioeconomic restrictions have to be considered. The full constellation increases significantly the risk for damage to oral health. When MA is used over a long period of time and in the absence of treatment, clinical symptoms in terms of Meth mouth syndrome cannot be excluded. Therefore, the authors recommend a specific prevention and therapeutic concept including educational campaigns for MA users and specialized dental care for MA patients.

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Conflict of interests The authors declare that they have no competing interests.

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