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**INVITED REVIEW**
**HOT TOPIC**

# Methamphetamine abuse and dentistry

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**Methamphetamine is a highly addictive powerful stimulant that increases wakefulness and physical activity and produces other effects including cardiac dysrhythmias, hypertension, hallucinations, and violent behavior. The prevalence of methamphetamine use is estimated at 35 million people worldwide and 10.4 million people in the United States. In the United States, the prevalence of methamphetamine use is beginning to decline but methamphetamine trafficking and use are still significant problems. Dental patients who abuse methamphetamine can present with poor oral hygiene, xerostomia, rampant caries ('Meth mouth'), and excessive tooth wear. Dental management of methamphetamine users requires obtaining a thorough medical history and performing a careful oral examination. The most important factor in treating the oral effects of methamphetamine is for the patient to stop using the drug. Continued abuse will make it difficult to increase salivary flow and hinder the patient's ability to improve nutrition and oral hygiene. Local anesthetics with vasoconstrictors should be used with care in patients taking methamphetamine because they may result in cardiac dysrhythmias, myocardial infarction, and cerebrovascular accidents. Thus, dental management of patients who use methamphetamine can be challenging. Dentists need to be aware of the clinical presentation and medical risks presented by these patients.**
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## Introduction

Amphetamines are a class of stimulant drugs that affect the central nervous system (Westfall and Westfall, 2006). Amphetamines have been prescribed to promote weight loss, treat attention deficit disorder and narcolepsy, and for treatment-resistant depression (Table 1; Westfall and Westfall, 2006). Legally produced amphetamines, such as methylphenidate and phenmetrazine, are sometimes diverted to recreational use (Cajetan Luna, 2001). Illegally produced members of the amphetamine class of drugs include amphetamine ('black beauties', 'white bennies', or 'speed'), dextroamphetamine ('dexies' or 'beans'), methylenedioxymethamphetamine (MDMA, known as 'ecstasy', 'XTC', or 'E'), methcathinone ('cat', 'bathtub speed', or 'goob') and methamphetamine ('crank', 'ice', 'crystal', 'glass', 'meth'; 'chalk' 'fire', 'tina', or 'speed') (Cajetan Luna, 2001; American Dental Association, 2005; U.S. DHHS NIDA, 2006, 2007).

During the counterculture movement of the 1960s, amphetamines were widely abused (Cajetan Luna, 2001; Rhodus and Little, 2005). Its use in Japan has been rampant as of the end of World War II (Cajetan Luna, 2001; Bolla and Cadet, 2007). The U.S. Food and Drug Administration (FDA) responded to the growing problem of amphetamine abuse with the passage of the Comprehensive Drug Abuse Prevention and Control Act of 1970. In the 1980s and 1990s cocaine became the drug of choice (Henry, 2001; Bolla and Cadet, 2007). However, methamphetamine has undergone a major resurgence among adolescents and people in their early twenties. Methamphetamine is widely used in California and in some Midwestern states where it is synthesized in

**Table 1** Amphetamines used in clinical settings and mood-modifying amphetamines used on the street

| |
|---|
| Mood-modifying amphetamines |
| Hyperactive children |
| Methylphenidate, phenmetrazine, pemoline, methamphetamine, dextroamphetamine, 3,4-methylenedioxy-methamphetamine (MDMA, Ecstasy) |
| Narcolepsy |
| Dextroamphetamine, pemoline, methamphetamine, 3,4-methylenedioxy-methamphetamine |
| Appetite control/aid weight loss |
| Benzphetamine, diethylpropion, 3,4-methylenedioxy-methamphetamine, methylbenzodiolbutanamine |

Modified from: (Henry, 2001).

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'home' laboratories (Cho and Melega, 2002; Cretzmeyer *et al*, 2003). Methamphetamine is the most widely illegally manufactured, distributed, and abused type of amphetamine.

Methamphetamine is a synthetic n-methyl homologue of amphetamine and was first synthesized in Japan in 1893 (Lineberry and Bostwick, 2006; Matteucci *et al*, 2007). It is a highly addictive substance that can be inhaled, snorted, smoked, taken orally or injected intravenously (U.S. DHHS NIDA, 2006, Grant, 2007). The preferred method of abuse depends on geographic location and has changed over time (U.S. DHHS NIDA, 2006). The Drug Enforcement Agency categorizes methamphetamine as a Schedule II drug consistent with its high potential for abuse (U.S. DHHS NIDA, 2006, 2007). Methamphetamine has limited medical uses but it is prescribed for the treatment of narcolepsy and attention deficit hyperactivity disorder (U.S. DHHS NIDA, 2006). The National Drug Intelligence Center's National Drug Threat Assessment Survey indicated that state and local agencies identify methamphetamine as their greatest drug threat, ahead of cocaine, marijuana, and heroin (U.S. DOJ, 2005).

## Pharmacology

Methamphetamine is white, odorless, bitter-tasting crystalline powder that easily dissolves in water or alcohol (U.S. DHHS NIDA, 2006). Methamphetamine powder can be further purified into the 'Ice' form that is usually smoked and very addictive (U.S. DOJ, 2005). Smoking methamphetamine leads to rapid uptake into the brain resulting in a 'rush' of extreme pleasure that lasts only for a few minutes but increases the addictive potential of methamphetamine and thus its adverse health effects (U.S. DHHS NIDA, 2006). The 'rush' experienced by users that smoke or intravenously inject methamphetamine is due to the release of high levels of the neurotransmitter dopamine in the brain (Davidson *et al*, 2001; Rawson *et al*, 2002; Nordahl *et al*, 2003). Dopamine appears to play an important role in the experience of pleasure associated with many drugs of abuse as well as other addictive behaviors such as gambling and thrill-seeking (Dackis and Gold, 1985; Grant *et al*, 2006; U.S. DHHS NIDA, 2006).

Methamphetamine is a powerful stimulant and even small amounts can increase wakefulness and physical activity while decreasing appetite (U.S. DHHS NIDA, 2006, 2007). Methamphetamine users will often appear malnourished due to appetite suppressant effects of the drug. There is the perception among methamphetamine users that it will enhance sexual performance by increasing energy levels and sustaining physical performance (Frosch *et al*, 1996; Bull *et al*, 2002; Semple *et al*, 2004b). Methamphetamine also blocks reuptake of norepinephrine (Seiden *et al*, 1976; Lake and Quirk, 1984; Dackis and Gold, 1985; Sulzer *et al*, 2005; Westfall and Westfall, 2006) resulting in increased sympathetic activity (Lee *et al*, 1992). The effects of this increase in sympathetic activity on the cardiovascular system includes cardiac dysrrhythmias, hypertension, and tachypnea (Westfall and Westfall, 2006). Initial effects of methamphetamine include hyperalertness, hyperactivity, euphoria, and talkativeness (Lee *et al*, 1992). Methamphetamine users also exhibit cognitive and emotional changes including paranoia, anxiety, depression, irritability, hallucinations, mood swings, and violent behavior (Sekine *et al*, 2001; Nordahl *et al*, 2003; London *et al*, 2004; U.S. DHHS NIDA, 2006). Some of these symptoms can last for months to years after the use of methamphetamine has ended (U.S. DHHS NIDA, 2006). Other effects of methamphetamine are listed in Table 2.

Chronic abuse of methamphetamine alters activity of the dopamine system in the brain leading to reduced motor function and impaired verbal learning that can lead to significant social, occupational, and medical impairments (Woods *et al*, 2005; U.S. DHHS, NIDA, 2006, 2007. Severe structural and functional changes in specific areas of the brain associated with emotion and memory likely contribute to the emotional and cognitive problems exhibited by those who chronically abuse methamphetamine (Sekine *et al*, 2001; London *et al*, 2004; Thompson *et al*, 2004; U.S. DHHS, NIDA, 2006, 2007. Chronic abuse of methamphetamine results in depletion of dopamine levels in the brain, which may be the mechanism underlying the dysphoria associated with withdrawal (Seiden *et al*, 1976). Withdrawal occurs when the person with substance dependence stops or reduces intake of the substance. Some of the signs of withdrawal from methamphetamine use are depression, anxiety, fatigue, and an intense craving for the drug (U.S. DHHS NIDA, 2006).

Intravenous administration of methamphetamine can lead to rapid development of dependence. Substance dependence occurs when an individual takes a substance

**Table 2** Clinical presentation of acute amphetamine toxicity severity signs and symptoms

| | |
|---|---|
| Mild | Nausea, vomiting, abdominal pain, diarrhea, palpitations, tremors, repetitive motor activity, hyperreflexia, dilated pupils, flushing or pallor, sweating, headache, restlessness, irritability, insomnia, xerostomia, bad taste, bruxism, trismus |
| Moderate | Hyperactivity, confusion, aggression, anxiety, hallucinations, muscle rigidity, tachycardia, hypertension, chest discomfort, tachypnea, dyspnea, mild pyrexia, dehydration |
| Severe | Delirium, hallucinations, paranoia, hyperpyrexia ($>40°C$), hypertension or hypotension, cardiac dysrhythmias, seizures, coma, renal failure associated with rhabdomyolysis |
| Potentially fatal | Ventricular fibrillation, myocardial infarction, acute cardiac failure, cerebrovascular accident (usually cerebral hemorrhage), extreme hyperthermia (may precipitate disseminated intravascular coagulation), repeated seizures, cerebral edema with brainstem compression secondary to hypoxia or hyponatremia |
| Withdrawal | Apathy, depression, lethargy, anxiety, sleep disturbances, myalgia, abdominal pain, increased appetite |
| Chronic toxicity | Paranoid psychosis with visual, tactile, or olfactory hallucinations; cardiomyopathy, vasculitis, possible serotoninergic hemotoxicity |

Modified from (American Dental Association, 2005; Beebe and Walley, 1995; Cajetan Luna, 2001; Henry, 2001; Rawson *et al*, 2002; U.S. DHHS NIDA, 2006; U.S. DHHS NIDA, 2007).

in larger amounts or over a longer period than was originally intended. A great deal of time may be spent in activities needed to get the substance, use it, or recover from its effects. The person continues to take the substance despite having persistent or recurrent social, psychological, and physical problems resulting from its use. The person gives up important activities because of substance use. A marked tolerance may develop to methamphetamine; hence, higher and more frequent doses are needed to produce the desired effects (Shaner, 2002; U.S. DHHS NIDA, 2006).

Overdose of methamphetamine produces angina, dyspnea, diaphoresis, palpitations, nausea and vomiting, confusion and hallucinations and could lead to ventricular fibrillation, acute cardiac failure, cardiovascular collapse, hyperthermia, and convulsions and can result in death if not treated immediately (Cajetan Luna, 2001; Henry, 2001; U.S. DHHS NIDA, 2007). Methamphetamine is often used in a 'binge and crash' pattern because the euphoric effects decline even before the concentration of methamphetamine significantly decreases in the blood (U.S. DHHS NIDA, 2006). Users then take more methamphetamine to maintain the euphoria. One study reported that for people who presented to an emergency department in which amphetamine toxicity was confirmed, the most common finding was altered mental status including agitation, hallucinations, suicidal ideation, delusion, and confusion (Derlet *et al*, 1989). Although methamphetamine abusers have been reported to take up to 15 000 mg $day^{-1}$ (Zalis and Parmley, 1963), as little as 1.5 mg $kg^{-1}$ has resulted in death (Lee *et al*, 1992).

Methamphetamine is metabolized by microsomal enzymes in the liver but chronic use does not increase microsomal enzyme levels (Lee *et al*, 1992; Westfall and Westfall, 2006). Methamphetamine is excreted by the kidney and plasma half-life ranges from 8 to 30 h (Shimosato *et al*, 1986; Cook *et al*, 1992; Lee *et al*, 1992; Shappell *et al*, 1996; Schepers *et al*, 2003). Thus, the half-life of methamphetamine is much longer than the half-life of cocaine ($<2$ h; Javaid *et al*, 1983; Chow *et al*, 1985). Withdrawal symptoms of methamphetamine may be more intense than those associated with cocaine and include severe depression with suicidal or homicidal ideation, hypersomnia, or sleeping difficulty (Rakel, 2002; Samet, 2004).

National studies indicate that $<1\%$ of pregnant women report using methamphetamine during their pregnancy (U.S. DHHS NIH, 1996; U.S. DHHS CDCP, 2004). More recently, a study that surveyed mothers attending medical clinics in cities with known problems with methamphetamine (Los Angeles, CA; DeMoines, IA; Honolulu, HI; and Tulsa, OK) reported that 5% used methamphetamine at some point during their pregnancy (Arria *et al*, 2006). Use of methamphetamine by pregnant women can result in loss of the fetus, low birth weight, premature births, congenital abnormalities, developmental delay, learning disabilities, memory deficits and even produce withdrawal-like symptoms in the baby upon birth (Oro and Dixon, 1987; Dixon and Bejar, 1989; Smith *et al*, 2003; Hohman *et al*, 2004). Also upon birth, prenatal exposure to methamphetamine was associated with neurobehavioral patterns of decreased arousal, increased stress, and poor quality of movement in a dose-dependent manner (Smith *et al*, 2008).

## Epidemiology

The World Health Organization estimates that over 35 million people worldwide use methamphetamine (United Nations ODCCP, 2000b). Methamphetamine abuse is a problem in the U.S., Mexico, South America, Middle East, Arabian peninsula, Asia and Australia (United Nations ODCCP, 2000a). The United Nations Office of Drugs and Crime Prevention ranks methamphetamine as the second most widely abused illicit drug in the world after cannabis (U.S. White House, 2003). In Canada, high rates of methamphetamine use is reported for street, gay and bisexual youth (Lampinen *et al*, 2006; Martin *et al*, 2006).

In 2005, the U.S. National Survey on Drug Use and Health: National Findings report stated that nearly 10.4 million (4.3% of respondents) people aged 12 years old and older have used methamphetamine at least once in their lifetime (U.S. DHHS SAMHSA, 2006c; U.S. DHHS NIDA, 2007). However, this represents a decrease from 11.7 million (4.9% of respondents) in 2004. The rates for past month and past year use of methamphetamine for persons age 12 years old and older have remained steady (for past month) or declined (for past year) since 2002 (U.S. DHHS SAMHSA, 2006a; U.S. White House, 2007). Although the number of past month users has remained relatively steady since 2002, there was a significant increase in the number of methamphetamine users who were dependent on or abused some illicit drug from 164 000 in 2002 to 257 000 in 2005 (U.S. DHHS SAMHSA, 2006a). The greatest prevalence of methamphetamine use within the last year is in young adults 18–25 years old (1.6%) as compared with youths 12–17 years old (0.7%) or adults 26 years old and older (0.4%) (U.S. DHHS SAMHSA, 2006a; U.S. DHHS NIDA, 2007).

Methamphetamine abuse and trafficking are increasing in the Midwest, Northeast, and Southeast regions of the U.S. while remaining stable in established markets in the Pacific, Southwest, and West Central regions (U.S. DHHS NIDA, 2004; U.S. DHHS SAMHS, 2006c; U.S. DOJ, 2006). The National Institute of Drug Abuse's Community Epidemiology Work Group (CEWG) is a network of researchers that monitors the patterns of drug abuse in 21 major areas of the U.S. In 2006, the CEWG reported that methamphetamine use remained at high levels in large western U.S. cities such as Honolulu, San Diego, Los Angeles, San Francisco, and Seattle but was increasing in rural and urban areas of the South and Midwest (U.S. DHHS NIDA, 2006). From 2002 to 2005, admissions for treatment of methamphetamine abuse increased in Arizona, Minneapolis/St Paul, Los Angeles County, Denver, and Atlanta (U.S. DHHS NIDA, 2007).

Among adolescents, methamphetamine use appears to be higher for Whites, Native Americans, and

Hispanics than African-Americans (Sexton *et al*, 2005; U.S. DOJ, 2005; Herman-Stahl *et al*, 2007; Iritani *et al*, 2007). Several areas monitored by the CEWG report that new groups of people are using methamphetamine, such as Hispanics and young people in Denver and African-Americans in Texas (U.S. DHHS NIDA, 2004). Additionally, use of methamphetamine by Native Americans is increasing in cities such as Los Angeles (Spear *et al*, 2007) and on Native American reservations (U.S. DHHS SAMHSA, 2005).

Methamphetamine-related arrests and the percentage of adult male arrestees that test positive for methamphetamine use have been increasing (U.S. DHHS NIDA, 2004). In Honolulu, Phoenix, and San Diego, one-third to one-half of adult females arrested tested positive for methamphetamine use in 2002 (U.S. DHHS NIDA, 2004). In a survey of methamphetamine users in Los Angeles County, over one-third had committed violence while under the influence of methamphetamine (Sommers *et al*, 2006). These acts of violence included domestic violence, gang-related violence, and random acts of violence, such as road rage and may occur because methamphetamine users can become compulsive, suspicious, and self-conscious (Cajetan Luna, 2001). Use of methamphetamine is associated with deaths related to homicide, suicide, and traffic accidents (Logan *et al*, 1998). State and local law enforcement agencies report that methamphetamine-related criminal activity has increased (U.S. DOJ, 2005). Specifically, about one-third of state and local law enforcement agencies identified methamphetamine as the drug that most contributes to violent and property crimes. Thus, the threat posed by trafficking and abuse of methamphetamine in the U.S. is high and increasing (U.S. DOJ, 2005).

## Treatment

Data from the Treatment Episode Data Set (TEDS) collected by the U.S. Department of Health and Human Services indicates that the number of methamphetamine-related admissions to publicly funded treatment facilities more than doubled from 47 683 in 1995 to 104 481 in 2002 (U.S. DOJ, 2005). The greatest percentage of the increase (52.6%) was related to referrals as part of criminal justice proceedings. Methamphetamine and amphetamines were the primary, secondary, or tertiary substance of abuse in 12% (228 800) of all treatment admissions in 2004, with admissions for methamphetamine abuse accounting for the large majority of these admissions (U.S. DHHS SAMHSA, 2006a). Methamphetamine/amphetamine was the primary substance of abuse in 8% (more than 150 000) of all admissions that year. The largest proportion of methamphetamine/amphetamine admissions across the U.S. were in small metropolitan areas and smoking was the most common route of administration in these admissions. However, the proportion of treatment admissions in which methamphetamine abuse was the primary reason was highest in Hawaii (56%) and San Diego (49%) in 2005 reflecting the high prevalence of methamphetamine abuse in the Pacific and Western U.S. (U.S. DHHS NIDA, 2007).

Methamphetamine-related visits to emergency departments throughout the U.S. increased by more than 50% from 1995 to 2004 according to data collected by the Drug Abuse Warning Network (DAWN) (U.S. DHHS, 2005; U.S. DHHS NIDA, 2006). In 2004, methamphetamine-related visits to emergency departments accounted for 4% of all drug-related visits. Currently, there are no specific medications that counteract the effects of methamphetamine (U.S. DHHS NIDA, 2006). Medical management should be supportive and directed to treat the pharmacologic effects exhibited by the patient. Acute mental disturbances or seizures are treated with a benzodiazepine, lorazepam 1–2 mg, i.v. or diazepam 5 mg, i.v., with repeated doses given to achieve needed sedation. Hyperthermia should be treated aggressively if rectal temperature exceeds 39°C. A rapid crystalloid fluid challenge should be given to reduce the pulse rate, raise the blood pressure and facilitate thermoregulation. In addition, rapid cooling measures such as mist/sprays, circulating fans and strategic ice placement should be used. Cardiovascular complications, tachycardia and hypertension are initially treated with intravenous benzodiazepines, with refractory cases of hypertension treated with sodium nitroprusside (Henry, 2001). If methamphetamine was taken orally, treatment is focused on gastrointestinal decontamination once the patient is stabilized. If it has been within 1–2 h of a life-threatening ingestion of methamphetamine gastric lavage may be indicated followed by oral administration of activated charcoal. If it has been longer than 1–2 h since the ingestion of the drug then charcoal alone is suggested. Syrup of ipecac is not recommended because its emetic effect may not occur soon enough to be of benefit (Henry, 2001).

There are no medications that prolong abstinence from or reduce the abuse of methamphetamine for individuals addicted to the drug (U.S. DHHS NIDA, 2006). The most effective treatments for methamphetamine addiction are behavioral therapies, including cognitive behavioral and contingency management interventions (U.S. DHHS NIDA, 2006). Those who inject methamphetamine have greater drug use during treatment, lower treatment completion rates, and thus poorer treatment prognoses than those who snort or smoke methamphetamine (Rawson *et al*, 2007).

## Methamphetamine abuse and dentistry

Patients who abuse methamphetamine may present to the dental office with specific clinical problems. If a patient reports abuse of methamphetamine, the dentist should carefully interview and examine the patient for associated dental problems. However, dental patients may not reveal that they abuse drugs for fear of being ostracized or legally prosecuted (McDaniel *et al*, 1995). Additionally, methamphetamine users commonly use other illicit drugs, such as marijuana/hashish, cocaine, heroin, hallucinogens (U.S. DHHS SAMHSA, 2006b). Therefore, dentists should be on the alert for signs and

symptoms that may indicate substance abuse. A thorough medical and dental history and a complete oral examination must be performed (Mallatt, 2005; American Dental Association, 2007). Telltale cutaneous lesions on the arms, such as subcutaneous abscesses, cellulitis, thrombophlebitis, and skin 'tracks' (chronic inflammation from multiple injections) often indicate parenteral abuse of drugs. Skin tracks usually appear as linear or bifurcated erythematosus lesions that can become indurated and hyperpigmented. An ill-defined febrile illness also can indicate a possible problem with parenteral drug abuse (Little *et al*, 2002). Patients who frequently miss appointments without good reasons or exhibit mood swings, violent outbursts, paranoid behaviors, and poor coping skills may be drug abusers and should be carefully evaluated.

Those who abuse methamphetamine may be at increased risk for acquiring and transmitting bloodborne diseases (Gonzales *et al*, 2006; U.S. DHHS, NIDA, 2007). Transmission of the human immunodeficiency virus (HIV) and hepatitis A, B or C viruses is increased in individuals that administer methamphetamine intravenously and by methamphetamine using men who have sex with men (Hutin *et al*, 2000; Semple *et al*, 2004a; Shoptaw and Reback, 2006). Those who administer methamphetamine by other methods are also at higher risk for sexually transmitted and bloodborne diseases because the intoxicating effects of methamphetamine can alter judgment and reduce inhibition resulting in users engaging in unsafe behaviors, including risky sexual behaviors (Cajetan Luna, 2001; Colfax *et al*, 2005; U.S. DHHS NIDA, 2006). Methamphetamine abuse may hasten the progression of HIV as animal studies suggest that methamphetamine increases viral replication and methamphetamine abusers exhibit greater neuronal injury and cognitive impairment caused by HIV (U.S. DHHS NIDA, 2006).

## Medical management

Counseling a patient who uses methamphetamine to get professional help for his or her substance abuse is a delicate subject. However, this is a responsibility of all health care providers, including dentists (American Dental Association, 2005). Discussing the situation with family members in order to encourage the methamphetamine user to seek professional help may be the best course of action (Little *et al*, 2002; Mallatt, 2005). However, the dentist must be aware of issues related to patient confidentiality.

Patients who are 'high' on methamphetamine should not receive any dental treatment for at least 6 h after the last administration of drug (Little *et al*, 2002; Goodchild and Donaldson, 2007). The plasma half-life of methamphetamine ranges from 8 to 30 h (Shimosato *et al*, 1986; Cook *et al*, 1992; Lee *et al*, 1992; Shappell *et al*, 1996; Schepers *et al*, 2003) and intoxication from methamphetamine can last for up to 24 h (Lake and Quirk, 1984). Due to the sympathomimetic effects of methamphetamine, the risk for significant myocardial ischemia and cardiac dysrrhythmias is the main concern in patients who are high on the drug. Local anesthetics with epinephrine or levonordefrin must not be used while the patient is high on methamphetamine as methamphetamine potentiates the response of sympathetically innervated organs to sympathomimetic amines (Lee *et al*, 1992; Little *et al*, 2002). This potentiation could result in a hypertensive crisis, cerebral vascular accident, or a myocardial infarction. Administration of general anesthesia or sedation may be associated with sudden death in methamphetamine users (Lee *et al*, 1992). Use of neuroleptic drugs in patients that use methamphetamine can result in elevated body temperature and neuroleptic malignant syndrome (Henry, 2001; Bolla and Cadet, 2007). Also, methamphetamine may potentiate the respiratory depressant effect of opioid drugs (Lee *et al*, 1992).

If a dental patient presents with signs of recent methamphetamine use, treatment should consist of supportive measures only (Lee *et al*, 1992). The patient's vital signs must be monitored as the heart rate and blood pressure can be elevated. In a patient experiencing toxicity from methamphetamine, the dentist should seek immediate medical attention for the patient. In the mean time, the dental team should provide basic life support care. Rapid breathing (tachypnea) precedes respiratory depression during methamphetamine toxicity so the patient should receive 100% oxygen treatment. Ventricular dysrhythmias may develop so the blood pressure and pulse should be monitored frequently. If the patient experiences cardiovascular collapse, cardiopulmonary resuscitation will be required. Patients may exhibit acute paranoid psychosis and may become violent (Lee *et al*, 1992). In this case, care must be taken to keep the patient calm and to assure the safety of the patient and the dental team.

## Oral manifestations

*Xerostomia*

Chronic methamphetamine abuse results in xerostomia, rampant caries, bad taste, bruxism, and muscle trismus (Di Cugno *et al*, 1981; Shaner, 2002; Saini *et al*, 2005). The cause of methamphetamine-induced xerostomia is unclear but may be due to activation of alpha-adrenergic receptors in the vasculature of salivary glands causing vasoconstriction and reduction in salivary flow (Shaner, 2002). Alternatively, stimulation by methamphetamine of inhibitory alpha 2 adrenoreceptors in the salivatory nuclei may decrease salivary flow rate (Saini *et al*, 2005). Dehydration related to methamphetamine-induced elevation of metabolism and increase in physical activity may also contribute to xerostomia (Shaner, 2002; Goodchild and Donaldson, 2007). Xerostomia significantly increases the risk for dental caries, erosion of enamel and periodontal disease (Shaner *et al*, 2006). The term 'Meth Mouth' has been used to describe the rampant caries often found in methamphetamine users (American Dental Association, 2005). Methamphetamine users describe their teeth as 'blackened, stained, rotting, crumbling, or falling apart' (American Dental Association, 2005). Poor oral

hygiene, high intake of refined carbohydrates, and increased acidity in the oral cavity from oral intake of methamphetamine, high calorie carbonated beverages, GI regurgitation or vomiting also contribute to increased number and severity of carious lesions in patients that abuse methamphetamine (Duxbury, 1993; Wynn, 1997; Shaner, 2002; American Dental Association, 2005; Klasser and Epstein, 2005; McGrath and Chan, 2005; Robinson *et al*, 2005).

The pattern of caries in chronic methamphetamine users is distinctive in that it involves the buccal smooth surface of the teeth and the interproximal surfaces of the anterior teeth (Duxbury, 1993; Shaner, 2002; Rhodus and Little, 2005). Caries associated with chronic methamphetamine use, while rampant, is different from that seen in other disorders, such as cocaine or narcotic abuse or postirradiation therapy for cancer. Similar to the pattern of caries in these other conditions, the caries occurs more frequently in the cervical region. However, the pattern of progression of the carious lesions is more similar to that seen with Sjogren's syndrome, wherein the carious lesions progress more slowly and go through periods of arrest instead of rampantly progressing (Rhodus and Little, 2005). The reasons for this pattern, although unclear, seem to be that some of the methamphetamine users actually practice some personal oral hygiene from time to time and therefore can slightly control the progressive rate of tooth decay. Dental caries, however, is a major problem in chronic methamphetamine users and defines the condition called 'meth mouth' (Figure 1). Often, restoration of teeth with advanced carious lesions due to methamphetamine is hopeless and the damaged teeth are extracted (American Dental Association, 2005). Patients, especially teenagers and young adults, who exhibit accelerated caries should be carefully evaluated for other symptoms and signs of methamphetamine abuse (American Dental Association, 2005).

**Figure 1** 'Meth mouth' – a long-tem methamphetamine user with rampant dental caries

*Bruxism*

Bruxism and excessive tooth wear may occur more frequently in chronic methamphetamine users (Venker, 1999; Richards and Brofeldt, 2000; McGrath and Chan, 2005; Curtis, 2006; Donaldson and Goodchild, 2006). Methamphetamine users have extremely high energy and neuro-muscular activity (Henry, 2001; Little *et al*, 2008), which can result in parafunctional jaw activity and bruxism (McGrath and Chan, 2005). Amphetamine-like drugs can produce choreiform motor activity (Rhee *et al*, 1988) that may involve facial and masticatory muscles and result in unusual patterns of tooth wear (Duxbury, 1993; Redfearn *et al*, 1998; Milosevic *et al*, 1999). Bruxism and muscle trismus can compound the effects of periodontal disease and produce symptoms of temporomandibular disorders, such as tenderness in the temporomandibular joints and masseter muscles (McGrath and Chan, 2005).

## Dental management

The most important factor in treating the oral effects of methamphetamine is for the patient to stop using methamphetamine. If the patient continues to use methamphetamine, it will be difficult to reduce consumption of high calorie carbonated beverages, improve nutrition and oral hygiene, and participate in dental treatment. Moreover, financial difficulties that result from abuse of methamphetamine will make it difficult for the patient to afford dental treatment leaving extraction of teeth the only possible treatment (Klasser and Epstein, 2005; Williams and Covington, 2006). Chronic methamphetamine abuse can result in psychosis and paranoia that can last for years after methamphetamine use is stopped (Davidson *et al*, 2001). Thus, the oral health care team must determine how well the patient is able to participate in his or her dental care. If the patient is able to participate, there are treatments that can improve salivary flow and reduce development and progression of caries. Meticulous oral hygiene with minimally abrasive fluoridated dentifrices and irrigation devices is very important. Frequent oral hygiene instruction and prophylaxis may be needed (Rhodus, 1989; Rhodus and Bereuter, 2000). The patient's nutrition must also improve with decreased

consumption of refined carbohydrates. The patient may benefit from working with a dietician. Frequent application of concentrated fluorides delivered either as a direct brush-on or by custom-made trays is imperative to prevent the rapid progression of caries (American Dental Association, 2005; Donaldson and Goodchild, 2006). Non-prescription fluoride rinses are inadequate. Sodium fluoride (5000 ppm) is preferred over stannous fluoride for several reasons (Donaldson and Goodchild, 2006). Stannous fluoride has an unpleasant metallic taste, may cause burning sensations in patients with xerostomia, and may stain enamel.

*Xerostomia*

Patients with methamphetamine-induced xerostomia should be counseled to drink 8–10 glasses of water per day and to avoid caffeine, tobacco, and alcoholic beverages due to their diuretic effect (Rhodus and Bereuter, 2000). Salivary substitutes, oral moisturizers, and artificial salivas may provide some relief from methamphetamine-induced xerostomia but are often inadequate. Most of these products are compounds of carboxymethylcellulose or hydroxymethylcellulose and do not have the correct viscosity for most patients. Their effect is often short-lived because they are not retained in the oral cavity for very long. Thus, they often provide little more relief than water. One commercially available artificial saliva was shown to provide more and longer-lasting relief than water in patients with xerostomia associated with Sjogren's syndrome and may be a promising therapeutic approach for treating patients with methamphetamine-induced xerostomia (Rhodus and Bereuter, 2000).

Another potential approach for treating xerostomia is pharmacological stimulation of the salivary glands. The U.S. FDA has recently approved the use of pilocarpine HCl (Salagen) and cevimeline HCL (Evoxac) for the treatment of hyposalivation in patients with Sjogren's syndrome. Pilocarpine is an alkaloid, parasympathomimetic drug extracted from the Pilocarpus plant and is a muscarinic-cholinergic agonist. Pilocarpine stimulates smooth muscle and exocrine secretions (Fox *et al*, 1986). The recommended dose of pilocarpine for most patients is 5 mg, three times per day but the dose can range from 2.5 to 15 mg, two to six times per day. Adverse effects of pilocarpine include diaphoresis, chills, and nausea but the incidence and severity of these effects are minimal. These doses usually do not produce significant cardiovascular effects (Fox *et al*, 1986). Pilocarpine stimulates production of saliva from major and minor salivary glands (Rhodus, 1997). Increased production of saliva from minor salivary glands may be especially important for protection against oral disease because minor salivary glands produced most of the secretory IgA, a powerful component of the oral cavity's immunological defense system (Rhodus, 1997). Patients with methamphetamine-induced xerostomia should be carefully evaluated and the patient's physician should be consulted to determine if there are any contraindications before prescribing pilocarpine. Caution should be exercised in individuals with hypertension, pulmonary or renal disease, cardiac dysrrhythmia or hypersensitivity to pilocarpine.

The primary endpoint for determining the therapeutic efficacy of pilocarpine is increased salivary flow. However, increased salivary flow is not necessarily accompanied by improvement of symptoms. Pilocarpine must be administered for a sufficient period of time before re-measurement of salivary flow in order to document clinical improvement. Careful and frequent follow-up evaluations (i.e. every 6–8 weeks) are important to assess the efficacy as well as to monitor for adverse effects so that the amount of pilocarpine and the frequency of administration can be adjusted. Pilocarpine may be continued indefinitely as long as the salivary flow continues to be stimulated and the patient experiences no serious adverse effects. Other pharmacological sialogogues, such as bethanachol chloride (Everett, 1975), bromhexine (Teichman *et al*, 1987) anethole trithione (Epstein *et al*, 1983), and interferon-alfa (Ship *et al*, 1999), have been shown to stimulate salivary flow but none has withstood extensive clinical evaluation in the U.S. for safety and efficacy and none has been approved by the FDA. Electrical stimulation of salivary glands remains controversial although one study has documented some improvement in salivary flow following the use of an electrical device (Talal *et al*, 1992).

*Pain control*

Methamphetamine users may present to the dental office due to dental pain as their oral health is generally poor. A likely situation is that the person seeks dental care between methamphetamine binges or when they are trying to regain control of their health (Laslett and Crofts, 2007). In this case, the dentist must thoroughly evaluate the patient, including determining when was the last time that the patient used any methamphetamine or other drugs. It must be emphasized to the patient that we cannot provide the most effective and safest treatment for them if we do not have a thorough understanding of their medical status. Methamphetamine's duration of action is generally 8–12 h but can be up to 24 h in cases of intoxication (Henry, 2001; O'Brien, 2006). If the patient has used methamphetamine within the last 24 h, the vasoconstrictor in the local anesthetic could result in further sympathetic drive to the cardiovascular system putting the patient at increased risk for cardiac dysrhythmias, hypertension, myocardial infarction, and cerebrovascular accidents (Turnipseed *et al*, 2003; McGee *et al*, 2004; Bolla and Cadet, 2007; Little *et al*, 2008). If local anesthesia is needed for delivery of dental treatment, a local anesthetic without vasoconstrictor should be used (American Dental Association, 2005; Donaldson and Goodchild, 2006; Goodchild and Donaldson, 2007; Little *et al*, 2008).

When a patient who uses methamphetamine requires analgesic medications, care should be taken to determine what other drugs the patient is using and when the drugs were last used because methamphetamine

users may also abuse other drugs, including prescription medications like opioids. A thorough dental examination is necessary to diagnose the source of the pain. Some methamphetamine users may try to obtain drugs from dentists by demanding pain medication for a dental problem they refuse to have treated. Dentists should not let patients know where drugs are kept or leave prescription pads out where they can be taken, and should not use prewritten prescription forms (Little *et al*, 2002). Methamphetamine users may claim to be allergic to codeine in an attempt to obtain a stronger drug such as morphine or hydrocodone. In these cases, non-steroidal anti-inflammatory agents can be used (Donaldson and Goodchild, 2006; Goodchild and Donaldson, 2007). However, in some cases users seek dental care between methamphetamine binges and the usual analgesic medications (i.e. non-steroidal anti-inflammatory drugs or narcotic combinations) can be used (Laslett and Crofts, 2007). Analgesics that cause central nervous system depressants are not contraindicated unless other depressants are being used by the patient at the same time (Lee *et al*, 1992). Consultation with the patient's physician may be required to balance the need for pain relief with the risk for drug interactions (American Dental Association, 2005; Laslett and Crofts, 2007). Some patients may use methamphetamine to reduce their anxiety related to their dental appointment. It is important to acknowledge the patient's anxiety and to offer other means of reducing it, including behavioral methods.

## Summary

Dental management for the patient who abuses drugs is always a challenge. The number of people abusing methamphetamine is leveling off and may be decreasing. However, dentists need to be aware of the clinical presentation and medical risks presented by these patients and to attempt to get the patient to seek professional help. Additionally, special attention is necessary to monitor for and treat oral manifestations associated with methamphetamine use including: rampant caries, enamel erosion, xerostomia, bruxism, and muscle trismus.

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