CHAPTER 5
SLEEP SHOULD BE REJUVENATING

A person can go weeks without food, days without water, but only minutes without air.

When Ben came to see me for the first time, his chief complaint was debilitating fatigue. At age fifty-three, he was so tired that he didn't even have enough energy to leave the house. Ben was a heavy snorer who regularly had trouble falling asleep, woke up frequently during the night, and crawled out of bed groggy each morning. He never woke feeling refreshed. He also ground his teeth at night and had hypertension.

VICTORY

Ben's victory was to get some sleep and return to having a normal level of energy again.

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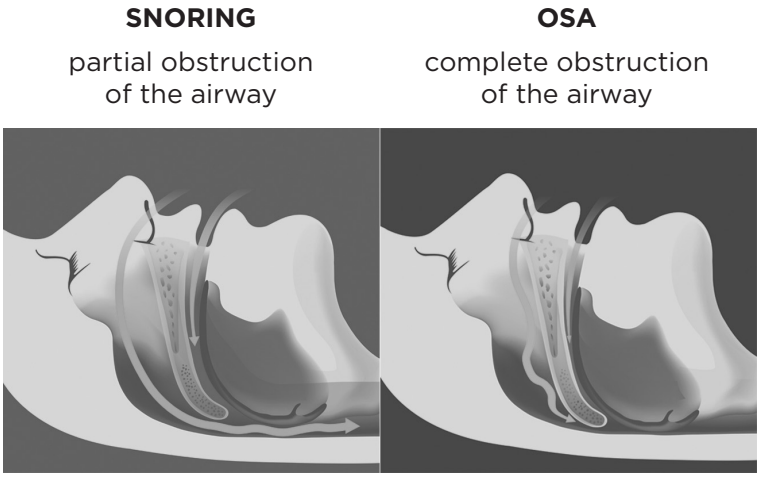
In Ben's clinical exam, we noted several signs and symptoms of obstructive sleep apnea (OSA) from the very beginning. He was unable to breathe through his nose due to chronic nasal congestion, so he primarily breathed with his mouth open—very unhealthy, as I've explained. He had a coating on his tongue, and his teeth were crooked and worn down from grinding at night.

As we explained these conditions to Ben, he became hopeful that they were the reasons for his fatigue. He was excited to undergo a sleep test and anxious to get the results so we could begin treatment.



THE NEED FOR SLEEP

The truth is, no one really knows why we sleep. We know that all animals sleep and that sleep is essential for survival.

We also know that seventy million Americans suffer from a sleep problem, and that sleep deprivation will eventually lead to death. A study conducted at the University of Chicago on rats proved that after eleven days of hyperstimulation and no sleep, the rats died.[12] While there was no anatomical cause for death, all rats in the study showed debilitated appearance and abnormal growths on the body. The sleep deprivation literally killed them.

Numerous, complex tasks occur during sleep. But sleep disturbances—conditions that prevent or affect sleep—can rob the body of proper sleep, leading to a cascade of negative health consequences.

So, simply put, humans need sleep to survive, and the quality of sleep ultimately determines quality of life. Sleep gives the body a chance to rest, recover, and rejuvenate. It is the body's way of filling the tank back up with gas.

Children need to sleep more than adults because that is when their body is actually growing. Everyone knows the term "sleep like a baby." That's a sign of good health—a healthy child sleeps like a rock. But just like adults, children can have sleep disturbances. We all know children who don't sleep well—they typically have behavioral and developmental issues, because their brain and body aren't rejuvenating as intended each night. The correlation between ADHD and sleep disturbances in children is now clear and well docu-

12 Everson, CA, BM Bergmann, and A. Rechtschaffen, "Sleep deprivation in the rat: III. Total sleep deprivation," *Sleep*, vol. 12, no. 1(February 1989:13-21.

mented. There are numerous studies illustrating this that I'll go into depth about in Chapter 9, but let's not overlook the obvious fact that inadequate sleep will affect our physical and mental performance the following day—this is something we all have experienced at some time. If this is a nightly occurrence, then we will have a host of deeper medical issues. It is no different with adults; we need our sleep—sound sleep, uninterrupted sleep.

Sleep consists of two distinct states, REM (rapid eye movement) and non-REM. These two states alternate throughout the night in four or five cycles over the course of four to ten hours, depending on the individual. Seventy-five percent of sleep is non-REM, while REM sleep occupies typically the last quarter or third of the night.

Non-REM sleep is the state of sleep responsible for physical restoration and is characterized by what are known as delta waves, which are slow brain waves. In adults, 90 percent of repair of damaged tissue occurs during sleep. Non-REM is the greatest portion of sleep in children, but the length of time a person spends in non-REM decreases from ages fifty to sixty-five. By age sixty-five, non-REM sleep can be absent.[13]

REM sleep typically accounts for 25 percent of a night's sleep. REM is responsible for improving learning, memory attention, and the ability to focus throughout the day. That is why staying up late to cram for a test may not be a good

13 Meir Kryger, Thomas Roth, and William Dement, *Principles and Practice of Sleep Medicine*, 5th ed. (Philadelphia: Saunders, 2010).

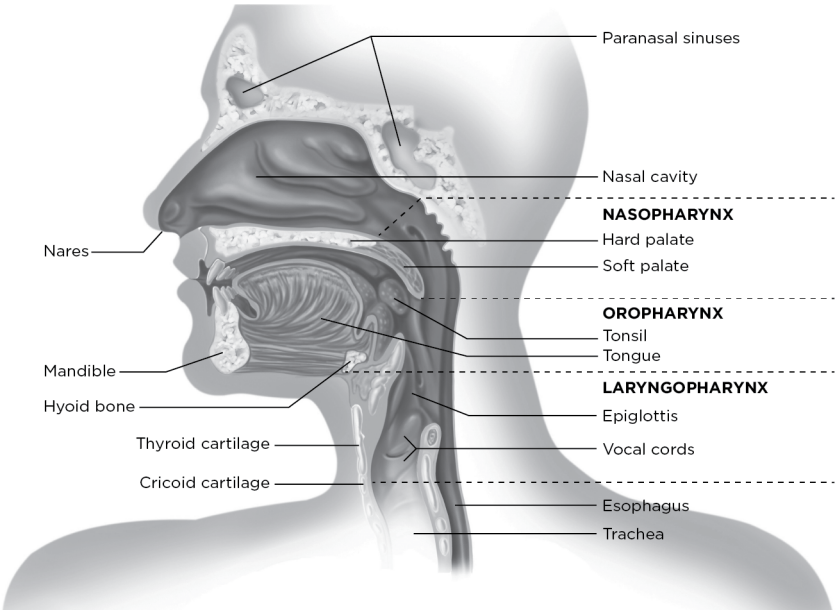
idea, because it ultimately causes a lack of REM sleep—meaning the new material just read won't be retained as well, if at all. You may remember it for tomorrows test but when you need that information weeks later it may not be recalled. REM sleep is characterized by reduced muscle activity and paralysis, which can predispose the airway to further collapse, worsening any sleep breathing disorders (SBDs) or resulting in a REM-dependent SBD.

CAUSES AND SYMPTOMS

What exactly are SBD and OSA? SBD occurs when a person stops breathing, either partially or completely, many times throughout the night. That can result in daytime sleepiness or fatigue that often reduces quality of life and inability to function throughout the day.

There are three types of SBD: snoring, upper airway resistance syndrome (UARS), and OSA. OSA is the most common form of SBD. It is associated with many negative health consequences, including chronic diseases and even death.

While we can't say for certain what one thing causes OSA, there are many predisposing factors contributing to this debilitating disease.



A small airway. Problems of the oral airway include a small opening anatomically, which increases the chances of the airway collapsing during sleep. The narrower a tube, the greater the likelihood of collapse.

Improper maxilla and mandible development. Improper development of the maxilla and mandible can also predispose an individual to obstruction of the airway. If the maxilla and mandible aren't fully developed forward and wide, it will reduce the dimensions of the airway. Again, this increases the chances of collapse.

Crooked teeth. Malocclusion (crooked teeth) indicate that there is inadequate space for the tongue inside the mouth.

The tongue ultimately determines how teeth are situated in the mouth, and malocclusion indicates that the tongue—a huge muscle—has limited room. When there's not enough room, the tongue can obstruct the airway. The orthodontic textbook *Contemporary Orthodontics* states, "Respiratory patterns are the primary determinant of the position of the head, jaw, and teeth."[14] That helps us understand the relationship between orthopedic development of the face and breathing. It doesn't mean, however, that someone with straight teeth can't have obstructive breathing—only that the likelihood increases with malocclusion.

Swollen airway tissues. Tonsils and adenoids are lymphatic tissue that rest in the back of the throat and nasal cavity. If these are swollen, they will also take up space within the airway and cause breathing problems.

Overweight. Obesity causes increased fat deposition in the soft-tissue passages of the airway and decreased muscle tone, making it more difficult to breathe and increasing the chances of an airway collapse at night.

Pregnancy. Pregnancy can cause increased inflammation and increased weight on the mother's diaphragm, leading to a higher chance of experiencing a collapse of the airway. That can lead to decreased oxygen levels (hypoxia) in the mother,

14 Proffit, William, Henry Fields, and David Sarver, *Contemporary Orthodontics* (St. Louis, Missouri: Mosby Elsevier, 2007).

which is not good for the baby and can increase the chances of preeclampsia during pregnancy.

Nasal obstructions. Nasal airway problems can also cause airway obstruction. These include a deviated septum (a crooked nasal bone), bone spurs in the nose, swollen nasal tissue, chronic sinus congestion, and allergies. These can decrease the flow of air through the nasal passages, decreasing the amount of oxygen getting to the lungs. When the muscles relax during sleep, that decreased airflow can cause OSA. A great study by Dr. M.F. Fitzpatrick and others illustrated that upper airway resistance during sleep and propensity to OSA are significantly lower while breathing nasally than while breathing orally. As I mentioned earlier in the book, nasal breathing is normal breathing. It is abnormal to routinely breathe through the mouth.[15]

COMMON SYMPTOMS OF SBD

There are several common symptoms of SBD and OSA. Historically, snoring and jerking awake gasping for breath are believed to be the only signs and symptoms of OSA. Although they are common, not everyone with SBD has those two symptoms. Here is what we commonly see in the new patients we welcome to our practice daily.

15 Fitzpatrick, M.F. et al., "Effect of nasal or oral breathing route on upper airway resistance during sleep," *European Respiratory Journal* 22 (2003): 827-832.

- ☐ Nerve pain
- ☐ Acid indigestion
- ☐ Kicking or jerking leg repeatedly
- ☐ Swelling in ankles or feet
- ☐ Morning hoarseness in voice
- ☐ Dry mouth upon waking
- ☐ Fatigue
- ☐ Difficulty falling asleep
- ☐ Frequent tossing and turning
- ☐ Repeated awakening
- ☐ Nighttime urination
- ☐ Significant daytime drowsiness
- ☐ Frequent heavy snoring
- ☐ Feeling unrefreshed in the morning
- ☐ Affecting sleep of others
- ☐ Gasping upon waking
- ☐ Told that “I stop breathing” during sleep
- ☐ Nighttime choking spells
- ☐ Morning headaches
- ☐ Night sweats
- ☐ Vivid dreaming
- ☐ Unable to tolerate CPAP
- ☐ Teeth grinding
- ☐ Teeth crowding

Another hallmark sign of OSA is insomnia. Insomnia is described as the inability to fall asleep or the drive to stay awake. Oftentimes, people with insomnia think their problem is just that they can't fall asleep. They don't realize that it may have something to do with the brain's drive to keep them awake. It is plausible to surmise that if the brain knows that you're going to start suffocating as soon as you fall asleep, it is going to work to keep you awake as long as possible, because it is conditioned to believe that on the other side of that suffocating sleep is death (not breathing, that is).

And sleep medications, it turns out, are really not a viable long-term solution for most insomnia patients. A recent study by the Mayo Clinic and the Human Health Institute investigated drug failure in 1,210 chronic insomnia patients, meaning that over-the-counter and doctor-supervised prescription drugs had failed to treat their insomnia. Once patients failed to get results with their medications sleep studies were performed on all the patients. The results of the study were astounding: 91 percent of the subjects suffered from undiagnosed OSA, a critical factor likely to be aggravating their insomnia.[16]

Waking up to use the restroom at night is also a common symptom of SBD. There are two reasons this might occur. One is that OSA places more pressure on the heart, resulting in an increased workload that increases the amount of fluid

16 "Insomniacs Failing Drugs Suffer from Sleep Apnea," Yahoo Finance, September 15, 2014, accessed October 19, 2017, https://finance.yahoo.com/news/insomniacs-failing-drugs-suffer-sleep-130000210.html.

going to the kidneys. That increases urine production during sleep, making a person wake up to void more often. The other reason is that a hormone (vasopressin, aka the antidiuretic hormone) produced during sleep helps retain fluid in the periphery, outside the bladder, during sleep, so the person doesn't have to wake up to void. When a person doesn't get to the appropriate stages of sleep, that hormone is not being produced, leaving the bladder to fill up and cause a need to urinate more frequently. In adults, that means getting up frequently at night to use the restroom. In children, it often means wetting the bed (nocturnal enuresis).

DEBILITATING HEALTH ISSUES

The aforementioned symptoms are often debilitating enough on their own, but when coupled with the long-term effects of OSA, the results can be devastating. OSA has been shown to lead to high blood pressure, heart disease, stroke, type II diabetes, metabolic syndrome, and liver problems. Aside from the health risks, patients often face declining job performance and jeopardized relationships due to the pain and fatigue they endure throughout the day.

Current literature supports the relationship between TMD and OSA. Patients diagnosed with TMD have an increased prevalence of OSA; patients diagnosed with OSA have an increased prevalence of TMD. My mentor, Dr. Olmos, writes of research on two separate studies of 2,604 and 1,716 patients:

> *Two studies tested the hypothesis that OSA signs and symptoms were associated with TMD. … Both studies supported a significant relationship between OSA symptoms and TMD with prospective cohort evidence finding that* ***OSA symptoms preceded first-onset of TMD****: patients with two or more signs and/or symptoms of OSA had a 73 percent greater incidence of first onset TMD*.[17]

OSA can also lead to TMD because clenching and grinding is felt to be a response to the stimulus of a collapsing or constricted airway. Over time, that repetitive trauma can cause inflammation and damage to the TM joint.

Dr. David Gozal of the University of Chicago has also linked untreated OSA to increased incidence and recurrence of cancer, due in part to the intermittent hypoxia (deficiency in the amount of oxygen reaching tissues) combined with the fragmented sleep that comes with OSA. He suggests that OSA promotes changes that can cause malignant tumors to transform and expand, which can lead to an increased probability of accelerated tumor growth and proliferation.[18]

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17 Olmos, Steven, "Comorbidities of chronic facial pain and obstructive sleep apnea," *Current Opinion in Pulmonary Medicine* 22, no. 6 (November 2016): 570–575.

18 Gozal, David, Ramon Farré, and F. Javier Nieto, "Putative Links Between Sleep Apnea and Cancer," *Chest*, vol. 148, no. 5(November 2015):1140-1147, accessed February 15, 2018 on U.S. Library of Medicine National Institutes of Health, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4631033.

***Hypoxia** is the deficiency in the amount of oxygen reaching tissues. **Hypoxemia** is the deficiency of oxygen concentration in the blood.*

Many of the debilitating health issues of untreated OSA stem from the increase in brain arousals and the decrease in oxygen levels. Hypoxemia (abnormally low oxygen concentration in the blood), is extremely damaging to the body's cells and causes destruction. Remember, nothing trumps breathing. OSA is damaging because the moment the brain experiences deprivation of air, it sends an arousal signal—which is essentially a shot of adrenaline (epinephrine) and cortisol—to stimulate the body to wake up and resume breathing. That is done repeatedly throughout the night and is extremely damaging to the body. Some experts say that OSA should stand for "obstructive sleep arousals" rather than apnea because the arousals damage the body and cause increased inflammation, which results in cellular destruction.

Decreased oxygen levels are also detrimental to health. Bodily tissues and organs need oxygen for survival. When breathing stops, oxygen saturation levels go down, depriving the tissues of oxygen. That leads to organ damage and tissue necrosis, or even death.

Hormone creation is also disrupted when sleep is constantly interrupted. The endocrine system has complex responses to sleep. The endocrine system is a collection of glands that secrete hormones into the circulatory system that

are then carried to other organs. During sleep, the secretion of some hormones (growth, prolactin, and luteinizing hormones) increases, while the secretion of other hormones (thyroid-stimulating hormones and cortisol) is inhibited.

Some hormones are tied to a specific stage of sleep. Growth hormone, for instance, is secreted during the first few hours of sleep and is generally released during slow-wave sleep—the delta-wave sleep I mentioned earlier. Delta sleep is the deep sleep in which the body is physically restored and growth actually occurs.

Cortisol—the stress hormone—is tied to the circadian rhythm (the sleep/wake cycle). Regardless of how well someone sleeps, cortisol is released during the day and peaks late in the afternoon. But when a breathing event wakes a person up at night, cortisol is secreted to keep the person awake so that they can resume breathing. That leads to an inordinate amount of cortisol being secreted at night, promoting wakefulness and ultimately raising stress levels. Remember that Mayo Clinic study mentioned earlier? Those patients suffered from insomnia and could not fall asleep. It is likely that their cortisol levels were extremely elevated due to their OSA.

Hormones from the pituitary gland have secretion levels intimately related to the sleep pattern. Production of melatonin—the sleep hormone—is also disrupted in patients with sleep disorders. Melatonin is released in the dark and is suppressed by light—as it starts to get dark outside, melatonin is secreted to promote sleep. Growth hormone (vital in adults

for tissue repair and in children for growth) and prolactin both peak at the onset of sleep. Testosterone secretion is elevated at the beginning of sleep and continues to increase through the night. Most hormones peak during non-REM sleep. Here again, sleep fragmentation and hypoxia from OSA cause abnormalities in hormone production and a rise in adrenaline.

Lastly, diabetes is a specific disease that affects the endocrine system's ability to produce the hormone insulin, and it is in turn affected by sleep. Adults who get less than five hours of sleep at night are more likely to have diabetes, compared to those who sleep seven to eight hours per night. Interestingly, people who sleep more than nine hours per night also have increased rates of diabetes. Patients suffering from OSA have increased glucose levels, and the more severe the OSA, the higher the glucose levels.[19] Thus, we know Type 2 Diabetes (non-insulin dependent diabetes) is a risk factor for OSA, and having OSA will increase the likelihood of developing OSA. In Type 2 Diabetes your body is resisting the effects of insulin or doesn't produce enough insulin to maintain your glucose levels. Unfortunately, as our diets get worse and worse, the rate of Type 2 Diabetes get higher and higher.

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19 Pamidi, Sushmita, Renee Aronsohn, and Esra Tasali, "Obstructive Sleep Apnea: Role in the Rick and Severity of Diabetes," *Best Practice & Research Clinical Endocrinology & Metabolism* 24, no. 5 (October 2, 2010): 703-715, accessed February 19, 2018 on U.S. Library of Medicine National Institutes of Health, *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2994098*.

Whatever the cause, fragmented sleep has a direct influence on pain thresholds, cognitive function, anxiety and depression, and other issues, both chronic and debilitating.

IDENTIFYING AND DIAGNOSING OSA

While a sleep study is always needed to confirm whether OSA is at play or not, evaluation of the anatomical structures associated with OSA is also incredibly important. To do that, we use advanced imaging technology and diagnostic tools to accurately identify potential areas of concern and create an optimal treatment plan.

There are often structural risk factors seen during an evaluation that allow us to identify that a patient might have SBD or OSA. Again, oral airway problems, mouth breathing, and bruxism all give insight as to what might be happening at night during sleep.

Facial development issues—a high palate, narrow dental arch, malocclusion (crooked teeth), excessive overjet (upper teeth jutting outward)—all may indicate OSA. The palate (roof of the mouth) is made up of two bones, connected by a suture, that are extremely malleable in children. The forces of breast-feeding and the movement of the tongue stimulate optimal growth of the palate. Proper nasal breathing coupled with breast-feeding and normal swallow leads to ideal facial development.

Oftentimes we see that patients who grew up without breast-feeding breathe through their mouths and have less-

than-ideal facial development. These craniofacial variations have proven to be risk indicators and predictive of SBD. These are findings that can only be revealed with a detailed medical history during the evaluation to discuss signs, symptoms, and risk factors of OSA.

Scalloped tongue is also predictive of OSA; it's a 70 percent indicator, according to ENT physician literature.[20] Scalloped tongue is identified by crenations, or notches, along the sides of the tongue caused by the tongue pushing up against the teeth all night long.

In evaluating patients with sleep disturbances and failure to improve their sleep with other techniques and treatment, it is essential to order a diagnostic sleep study. Right now, a sleep test diagnosed by a sleep physician is the only way to confirm or rule out SBD. We cannot rely on the observations of a bed partner. Hopefully the bed partner is busy sleeping soundly themselves. Also, I often tell patients that while snoring is a hallmark sign of OSA, the sound of not breathing is silence—so if someone is not breathing intermittently, there is really nothing to hear.

A diagnostic sleep study can determine whether SBD is present, and if so, the severity of the disorder. Physicians, physician's assistants, dentists, chiropractors, nurses, and

20 Weiss, TM, S. Atanasov, and K.H. Calhoun, "The association of tongue scalloping with obstructive sleep apnea and related sleep pathology," *Otolaryngology-Head and Neck Surgery* 133, no. 6 (December 2005): 966–71, accessed February 19, 2018 on U.S. Library of Medicine National Institutes of Health, https://www.ncbi.nlm.nih.gov/pubmed/16360522.

primary care doctors can order diagnostic sleep studies—depending on the hospital system, insurance, and the state. However, only a sleep physician can review the sleep test and provide the actual diagnosis. It's kind of like a radiologist reading a hospital CT scan. Tests may be performed by a radiology tech, but the patient never really meets the radiologist who reads the results of the tests and makes a diagnosis that is delivered to the treating physician. While we prefer the patient to meet face-to-face with a sleep physician, it is not always possible, as there are not enough sleep physicians to feasibly see all the patients diagnosed with SBD.

There are basically two types of sleep tests: home tests and in-lab tests. Home tests are commonly referred to as HSTs (home sleep tests) or out-of-center sleep studies. Home tests are done in the confines of the patient's home and include a monitoring/recording unit along with a strap that wraps around the chest, a probe worn on the finger, and a cannula worn by the nose. The devices record breathing activity, body movement and position, oxygen levels, and respiratory effort throughout the night. That information is then scored and reviewed by a registered polysomnographic technologist (RPGST) and a sleep physician to render a diagnosis.

An in-lab sleep test (polysomnography/polysomnogram) uses more detailed equipment to measure brainwave activity (electroencephalography, or EEG). This test is actively monitored throughout the night by a sleep technician. This information is then similarly scored and reviewing by an RPGST and a sleep physician to render a diagnosis.

Every day, I explain the sleep tests like this: Home sleep tests are more accurate sleep but less accurate data. In-lab sleep tests are more accurate data but less accurate sleep. Generally speaking, patients sleep better at home and in their own beds. However, home sleep tests can have false negatives, inaccurately identifying someone as being "normal." This is where a good clinical history and follow-up is needed to order subsequent testing as needed. The trend is certainly going toward more home testing, as the technology is rapidly improving and if a home test doesn't show us the results needed, an in-lab test can always be ordered.

Regardless of which study is used, the results of the study are reported as a score referred to as the respiratory disturbance index (RDI), the apnea-hypopnea index (AHI), or the respiratory event index (REI). These terms are relatively synonymous, and it depends on the sleep lab and the sleep physician as to which term is used. RDI encompasses RERA (respiratory effort-related arousal), while AHI and REI are just inclusive of apneas and hypopneas. The events are totaled and divided by the hours of sleep, which results in an index.

THREE MAIN SCORING CRITERIA WITH DIAGNOSTIC SLEEP TESTS.

Apnea – a cessation of breathing for at least ten seconds (at least a 90 percent reduction in airflow from baseline breathing) associated with a 3 percent reduction of blood oxygen satura-

tion levels, resulting in an arousal to resume normal breathing.

Hypopnea – a 30 percent reduction of airflow for at least ten seconds associated with a 3 percent reduction in blood oxygen saturation levels, resulting in an arousal.

RERA – (respiratory effort-related arousal) characterized by obstructive upper airway airflow reduction associated with increased respiratory effort that resolves with the appearance of arousals.

Basically, what these indexes report is how many times per hour of sleep the brain is awakened due to a respiratory event or a break in breathing. OSA is defined as a cessation of breathing during sleep for at least ten seconds. A score of normal is equal to less than five events per hour of sleep, while higher scores are classified as shown in the following table.

APNEA-HYPOPNEA INDEX (AHI)

SEVERITY	AHI PER HOUR	
	Adults	**Children**
Mild	5-15	1-5
Moderate	16-30	6-10
Severe	>30	>10

BEN'S VICTORY

When Ben's sleep study results were returned, it showed severe sleep apnea. At 36.9 breathing events per hour of sleep, he was waking about once every two minutes. Think about how that kind of fragmented sleep would affect a person the following day. What's interesting is that Ben wasn't aware that he was waking up once every two minutes. He was so tired and exhausted that his brain basically would wake up just enough to resume breathing, and then he would fall back asleep.

At first, Ben needed care from our trusted referral partners in order to adequately treat his severe sleep apnea. He was originally started on a continuous positive airway pressure (CPAP) machine, which supplied him with air through a hose and a mask that he wore over his nose and mouth at night while he slept. Ben tried the CPAP diligently for weeks, but ultimately, he could not tolerate it, so under the order of his sleep physician, we customized an oral appliance for him to wear nightly. Ben's specific appliance was designed to prevent the retrusion of his mandible while sleeping. By preventing his mandible from falling back, the appliance holds his tongue, soft palate, and associated tissue slightly forward and prevents the collapse of his airway.

After the very first night of sleep, Ben reported that he woke up feeling amazing. He slept soundly through the night and did not wake up fatigued. And his wife reported that his snoring had stopped. Now, everyone doesn't have such quick results, but our ultimate goal is to achieve their victory.

In the months following, we continued to see Ben to adjust his appliance and ensure that we stayed on track for properly treating his OSA. During that time, he also needed treatment for chronic nasal congestion by an ENT physician.

Today, I'm happy to report that Ben's OSA is being adequately controlled, as validated by a follow-up sleep study with his appliance in place. His breathing events have dropped below five per hour, which is well within the normal and acceptable range for an individual. Ben says his treatment improved life for him and everyone around him. As Ben describes it, he went from a zombie-like existence to being able to walk miles every day—that's rewarding to hear from a patient.

"There's no more snoring, thank God, and [I'm] breathing easier—everything in that respect has just made my life much better. It's better for me, for my wife, for my children. … I feel healthier. And I was in a pretty bad state, so if it can work for me, it can certainly work for others who don't have the condition nearly as bad as I did."

Sometimes, I think it would be great if patients came to us with just one problem, whether that's just facial pain or only a problem sleeping. But unfortunately, that's not the case. Often patients are plagued with both pain and sleep problems, which mandates that we evaluate their chronic facial pain along with their chronic sleep disturbances, and often we've found that chronic sleep disturbances and facial pain cannot be separated. They're intimately related, and we

have to sift through the patient's clinical history to determine the primary cause of the problem.

That often leads to a "chicken and egg" conundrum: Which came first? Did the facial pain aggravate the chronic sleep problem or did the chronic sleep and breathing problem aggravate the patient's chronic facial pain? In the next chapter, I will discuss this conundrum and explain which came first.