Chapter 9
Strategies for Addressing Mouth-Breathing Treatment with an "Adequate" Nose

> Tis of little use ... for any to strive to get out of their elements, since it's natur' to stay in 'em, and natur' will have its way.—James Fenimore Cooper in Deerslayer

We have spent the past few chapters carefully explaining the difference between true nasal *obstruction* and the more common nasal *underuse*. We discussed how the symptomatology can be similar, and even experienced physicians can be confused between findings of actual blockage (cartilage or bone in non-ideal position), and reactive tissue enlargement due to chronic mouth-breathing (i.e., turbinate or adenoid hypertrophy). Once this concept was developed and we discussed strategy to differentiate the two opposing conditions, we spent Chaps. 7 and 8 describing a strategy to address, classify, and treat the *truly* obstructed nose. The goal of this chapter, in contrast, assumes that a patient has been confirmed to have an adequately functioning nose. *Adequate* function can be the result either after surgical framework repair, if they used a variety of nasal dilators that adequately restored the airway at night, or most commonly if they were fortunate enough to have a good enough nasal architecture to have a baseline adequately structured nose. If *these* patients are mouth-breathing, it is NOT due to nasal obstruction, but to nasal underuse related to tone and jaw/facial structure (see Chap. 5). To summarize, this underuse creates a buildup of negative pressure in the nasal cavities and sinuses, and the patient develop symptoms that mirror true nasal obstruction.

In this chapter, unlike the past two, we will employ strategy in this chapter to consider complementary treatments to prevent or treat nasal *underuse* (coined as disuse by Guilleminault and colleagues) [1], and not obstruction simply by utilizing tactics to achieve mouth-closure at night.

I will not pretend to know any one best way to achieve night-time jaw closure. Despite what most experts say, there probably is not one perfect one-size-fits-all solution. In lieu of an ideal solution, I will discuss alternatives to reverse jaw-relaxation mouth-breathing by breaking the concept into two main categories: I. The temporary, yet effective wearable or insertable mouth-closure device that can be very effective, but uncomfortable, and II. The long-term mouth-closure or

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musculoskeletal modification that can have nebulous outcomes but can be permanent and ideal if success is achieved.

Short-term (Temporary) Mouth-closure devices

1. Jaw-closure wearable devices (Garments/straps/tape)
2. Intra-oral appliances to support the jaws

Long-term Mouth-closure solutions

3. Muscle re-training exercises (Myofunctional therapy)
4. Jaw expansion appliances
5. Jaw expansion surgery

Being an individual with a generally adequate nose but suffering from night-time jaw-relaxation, I myself am prone to night-time mouth-breathing, and thus when left untreated, like the rest of my fellow *Homo sapiens*, can experience the varied symptoms of nasal underuse (disuse). Because of this, I have through years of self-experimentation and practice found semi-successful solutions for my own problem. Also, as my father and one of my sons bear great resemblance to me, and face a similar problem of nightly jaw-relaxation, I have also been able to seek solutions for an older and younger variation of myself, and I will discuss these findings as well. These solutions are neither perfect nor the ideal solution, and I of course have not tested all of the possible variations, but I will begin with the answers that have brought me some personal success and also present what the evidence from the medical literature has to say about these solutions

Temporary Mouth-Closure Devices

Jaw closure wearable devices (Garments, straps, and tape)

As is obvious by the name, this class of therapeutic strategy involves the use of external devices, or even sleep position to keep the jaw closed during sleep where low tone stages cause relaxation of the muscles that support the jaw and lips, or worse, where counterproductive musculature actually causes jaw opening due to habitual mouth-breathing. I have found this class to be superior in achieving immediate results (and rest) compared to other classes, because if the device successfully keeps the jaw locked closed, the tongue will remain locked between the upper and lower jaws and thus cannot collapse into the airway. This strategy permits the adequately functioning nose to do its "job" humidifying the inspired air and maintaining a retro-lingual and retro-palatal column of air. Unfortunately, applying enough stable pressure to the undersurface of the jaw in the correct vector of lift can be both uncomfortable for the user (due to compressive pressure on the skin) and have a lack of stability if the patient is a restless sleeper. So, if an external jaw support device is too uncomfortable for the user, or too unstable during deep sleep, or does not provide enough force to counteract the forces of jaw opening, it will be useless. If the nasal airway is inadequate to independently provide respiration, the device is also

not helpful, but as long as the lips are not taped shut (see below), mouth-breathing is still possible if the device was used inadvertently by someone with too much nasal obstruction, or who has developed acute nasal obstruction. Finally, recommending these devices to patients will frequently cause them to look at you like you have lost your mind. But, be persistent if you think it is warranted. They will thank you later.

A study from Taiwan testing a rudimentary silicone device that the authors called a POP (porous oral patch) used objective measures of efficacy of a mouth-closure device [2]. The study has one of the best explanations of how mouth-breathing, nasal obstruction, snoring, and sleep apnea are related. Although from my gathering, this brilliant paper is largely ignored by the surgical community.

The authors begin by introducing their project, "In patients with OSA, the mouth is opened during sleep and is associated with inferior movement of the mandible that decreases the pharyngeal diameter. Mouth opening during sleep is also accompanied by a reduction in the length of upper airway dilator muscles that lie between the mandible and the hyoid bone, which exacerbates snoring and OSA. Relief from severe nasal obstruction during sleep is related to a significant normalization of mouth breathing, enhancement of the sleep-stage architecture, and a modest reduction in the severity of OSA. However, many snoring individuals and patients with OSA are accustomed to opening their mouths during sleep in spite of the patent nasal pathway. In these patients, the symptoms of snoring and OSA may persist despite undergoing nasal or oropharyngeal surgery. Therefore, close-mouth-breathing must be maintained during sleep to reduce snoring and OSA for these patients. Conventional dental appliances may stabilize the upper airway by preventing the mouth from falling open during sleep. However, the dental appliance may cause excessive salivation, temporomandibular joint discomfort, and changes in occlusive alignment. This study used a porous oral patch (POP) to treat patients with mild OSA and OMB during sleep. The subjective and objective outcomes were evaluated" [2].

They went on to describe their study as a "prospective study conducted on patients who complained of snoring and habitual mouth opening during sleep, as observed by the bed partner. Each patient underwent a complete workup, including a thorough medical history review, physical examination, overnight polysomnography, and fiberoptic nasopharyngolaryngoscopy with the Mueller maneuver." They enrolled patients with mild obstructive sleep apnea (OSA) by polysomnogram, and excluded patients with severe pathology like very large tonsils or severely obstructed septal deviation after institutional review board approval. The patches worn by the patients, called the Porous Oral Patch (POP), consisted of a silicone sheet, and polyurethane foam and film, and is placed over the mouth during sleep, sealing the oral opening. They tested this over three nights and measured subjective and objective polysomnographic and cephalometric outcomes, compared using statistical measures. In this 30 patient study, "Every individual was able to sleep while wearing a POP and did not appear to have removed it … The median Apnea hypopnea index (AHI) score was significantly decreased by using a POP from 12.0 per hour before treatment to 7.8 per hour during treatment ($P < 0.01$ Wilcoxon Rank Test)." The

POP also radically improved symptoms of snoring, dry mouth, and drooling as well as cephalometric airway measures [2].

The research team wisely evaluated "*only patients without nasal obstructions*," revealing their insight into the cause of the mouth-breathing (not the nose, but tone!). The flaw of the study besides its relatively small number of patients is possibly that the design of the device could be improved. Specifically, if you look at the figure, the device only closes the lips. However, while they discuss chin straps, I have found from personal experience that support of the jaw in a closed position is critical to mouth-closure efficacy and simply closing the lips is not enough [2].

While one study one showed no objective improvement in AHI [3], when looking at the chin strap utilized by the researchers, it is obvious that this device is neither stable nor lifting of the chin, but quite flimsy with the incorrect vector of lift. If the device fails to close the jaw comfortably during the night, the device is automatically a failure. However, failure of a single device does not mean that mouth-closure does not prevent apnea. This is an error in logic. It is my opinion that with complete mouth-closure, apneas will cease. However, because no treatment studied adequately achieves *complete* mouth-closure, we are led to believe that mouth-closure is only a footnote in the management of sleep apnea, especially when we are motivated to find a surgical option. In reality, it is likely that the efficacy of the treatment is proportional to the degree of the mouth-closure. However, the better the device achieves mouth-closure during sleep (which requires substantial force), the less comfortable the device will feel.

Personal Experience and Thoughts on Temporary Mouth-Closure Devices

At some point several years ago, around age 42, I became aware that I was snoring, (my wife let me know) and mouth-breathing (I awoke with a dry mouth), particularly when supine, or after a very long day that left me exhausted. Initially, I assumed that this was the inevitable manifestation of age and paid it little attention. At around this same period, I was working with a device company in the development of a nasal valve device to treat obstruction. During this time, a particularly astute executive with the company named Joel Granier told me that he was puzzled how the nose was involved with sleep apnea. Initially, I responded that by most accounts the literature reported only a slight symptomatic association between the two, and that largely nasal surgery could only be performed to "improve CPAP compliance," as was the mantra of the time. But, the question got me thinking, and after some investigation, and even some clinical studies I became convinced that the nose was intimately related to OSA, and that the primary culprit was obstruction of the nasal valve. So, applying the concept to myself, I began to self-experiment with Breatheright™ strips of many varieties, even doing home sleep studies on myself to test efficacy. However, this was to almost no avail as the strips at best marginally

improved my symptoms, despite diminishing any nasal blockage. How, I wondered, could mouth-breathing be the problem, when improving nasal airflow did nothing to alleviate my OSA symptoms or AHI?

Unexpectedly, a cleaning by a dental hygienist turned-up the solution in ways I never could have imagined. My hygienist at the time, who eventually attended dental school noticed excess plaque on the lingual surface of my lower incisors, and he told me that this meant that my mouth-breathing at night was quite severe. I of course informed him that I was aware of this and had been studying the problem for years and self-treating. He patiently listened to my explanation, and then suggested that I tape my mouth closed at night, as he had heard of this concept from an expert in California on YouTube™. After I was done laughing and ridiculing the foolishness of his suggestion, I looked up the videos he suggested that night. But, as foolish as it sounded, I couldn't resist trying it that very night. Amazingly, my wife informed me that I had less snoring that night, and I experienced less dry throat sensation on waking up and had more energy the next day. The lip taping was a huge step in the right direction toward the basic understanding that mouth-breathing was independent from nasal obstruction. In other words, I previously thought, as counter-intuitive as this sounds that nasal obstruction was THE cause of mouth-breathing, as I suspect many of my fellow clinicians do. As I was learning, though, mouth-breathing is actually related jaw-relaxation, NOT blockage of the nose (see Chap. 5). So, I finally switched my goal of attempting to solely dilate the nasal valve of myself and OSA patients, and re-focused the goal on maintaining an ADEQUATE nasal airway with nasal dilators or valve/septal surgery but more importantly supporting jaw, lip, and mouth-closure during sleep. Over time, the simple mouth tape evolved into peri-oral taping, and very strong jaw support tape that was adequate to keep the mouth entirely closed at night even with some loosening with salivation or stretching. I tested the jaw/mouth-closure taping on myself combined with nasal dilator tape using a Watermark home sleep study test system all night in the supine position with three nights with, and three nights without the device (unpublished data—Fig. 9.1). As you can see, my supine AHI decreased from the mid-teens to the low single digits, as in the POP study. Multiple family members use similar systems, from diving hoods cut to support the chin, to commercially available anti-snore devices. For all of us, jaw support devices, regardless of the style, material or type has been life-changing, and has the possibility to improve the lives of millions of people who have symptoms of nasal underuse/nasal disuse or mouth-breathing, many of which are currently treated in a compartmentalized fashion by many types of providers, and includes, headache, facial pressure, negative ear pressure (popping and hearing loss), sore throat, upper respiratory infection (URI), and the many variations of chronic fatigue (actually sleep apnea). Currently, we are in the early stages of obtaining Institutional Review of a clinical study that tests split-night sleep studies using jaw support devices in adult and pediatric patients in patients with an adequate functioning nose. As mentioned, the "Catch-22" of jaw support devices that keep the mouth closed is that efficacy is inversely proportional to comfort. In other words, there is a substantial amount of force required to reverse the pull of gravity to maintain a stable jaw closure for the

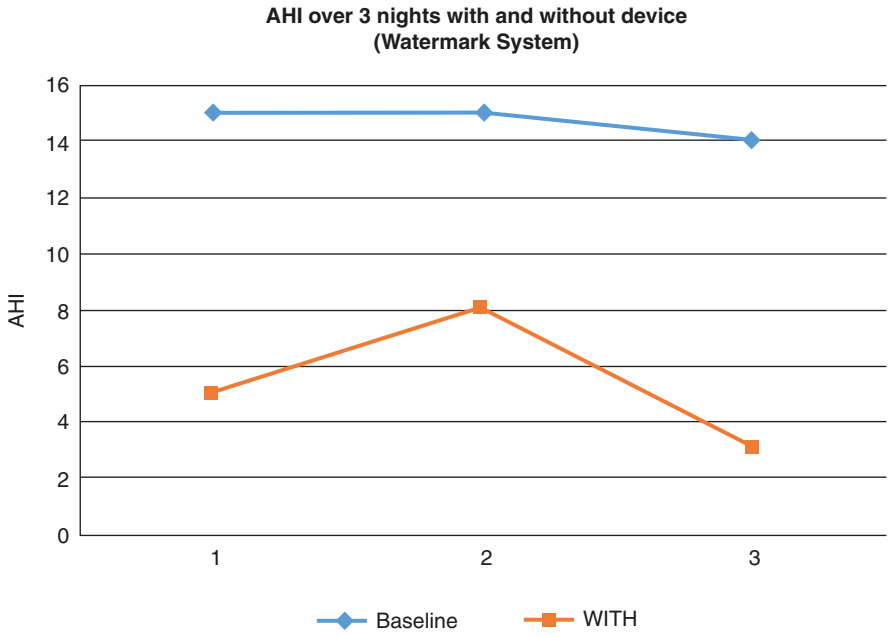

Fig. 9.1 Supine AHI (*Y*-axis) of author in 2015 over three nights (*x*-axis), both with (blue) and without (orange) the jaw closure device (three nights each for a total of six nights) using the Watermark home sleep study system

duration of the night. This force can feel quite uncomfortable on top of the head or as tape pulling on the cheekbones. The device is ineffective if it is too uncomfortable to wear, and ineffective if it fails to completely lift the jaw to a closed position. A common error is to use a jaw closure device like a chin strap that either uses the incorrect vector, or is so "comfortable" and slim that it fails to close the mouth. This "comfortable" jaw strap stays on possibly, but fails to do its job, and the wearer instead of trying a more effective but less comfortable version assumes that the jaw-closure concept is ineffective, so abandons it completely. The ideal device worn externally could be a web of jaw supporting tape, anchored to the zygomatic arch skin under some tension or could be a tight "diving hood" type device that has a broad vector of vertical lift below the chin, and diffuses the pinpoint tension of a typical narrow chin strap over the surface of the scalp. Finally, it will be resistant to sweat and saliva, as well as resistant to dislodgement during restless sleep. Can this ideal device be found? Probably, but may end up as different solutions for different individuals, instead of a perfect solution for all. Even in my own family, I use Durapore™ tape from 3 M, one of my children uses a modified latex diving hood with ear-holes cut, while a parent uses a continuous positive airway pressure (CPAP) device. All with generally the same problem to various degrees, but with multiple solutions due to personal comforts and preferences.

Oral Appliances

There is a tremendous amount of information about oral appliances and sleep apnea in the literature and on the web. I have no problem with the use of oral appliances for OSA as long as they keep the mouth closed and do not cause chronic change to occlusion or function of the temporomandibular joint (both real possibilities). To paraphrase Douglas Adams in his fictional two-word entry of the description of the planet earth in "The hitchhikers guide to the galaxy," all I can say about these devices in general is that to me, they appear generally benign [4].

The jaw advancement devices that take mouth-closure to a new level (beyond normal occlusive closure) sound particularly uncomfortable to me, and I have no desire to test these devices, nor do I have an interest in exploring the temporomandibular joint discomfort that I would imagine goes along with these devices. The literature seems to consider the effects of the mandibular advancement devices (MAD) as controversial on its effects on the bite or Temperomandibular joint (TMJ) condyle [6, 7].

A final note on temporary mouth-closure devices: Mouth or jaw closure devices should only be used with an adequate nasal airway. This means being able to breathe comfortably for several minutes in the office with the mouth closed and not any occasional mouth-breaths. In an ideal world, for physicians to recommend these devices, a physical exam that determines that the nasal airway is adequate, a NOSE score below 30 [5], or use of a device like the thermal imaging device that has a ΔT value above the threshold considered as an adequately functioning nose would be assessed before recommending or dispensing one of these devices (see Chap. 5). The combination of these assessments could be stored in a document similar to the audiogram and could be called a "thermo-nasogram."

Most importantly, after functional rhinoplasty, where the main goal may be to convert one from a mouth-breathing individual to a nasal-breathing individual, once the adequate nasal airway has been established, jaw support or mouth-closure devices may make an excellent adjunctive treatment modality.

Long-Term Strategies to Prevent Mouth-Breathing via Musculoskeletal Improvement

The long-term, but less direct approach to prevention of mouth-breathing is to attempt to enhance the musculoskeletal function and structure to encourage nocturnal closure of the jaw. There is much written about this online, and in the medical literature, and there are many approaches employed in this process. However, because it is by definition an *indirect* treatment, instead of the direct mouth-closure techniques from the previous section, there is really no way to know for certain that these long-term techniques truly work. Clinical studies are helpful, as we can see shortly, but because there are so many confounding variables, like continued growth in children and people who concurrently use multiple techniques, I find that even

good clinical data from very reliable sources cannot be completely reliable. From a reasoning perspective, I recommend using short-term mouth-closure devices or positioning (avoiding the supine position during sleep as this is most apnea and mouth-breathing prone) [8] while concurrently pursuing long-term solutions. I do this both for myself, my family, and I recommend this to my patients too.

Myofunctional Therapy

First, I will discuss an entity known as "myofunctional therapy," which is essentially a version of physical therapy designed to strengthen the tongue and jaw muscles to encourage nightly jaw closure. This therapy is typically coached by someone from the dental profession, frequently an individual trained along the dental hygiene pathway with extensive knowledge of non-procedural care of the oral cavity. Myofunctional therapy consists of isometric and isotonic exercise that target the function of the lip as well as the structures of the pharynx. Despite a heterogeneity of exercises, a systematic review and meta-analysis by Camacho et al. showed a consistent improvement (approximately 50% AHI reduction) in objective sleep measures by polysomnography in all age groups [9]. While the exercises were variable, the effects were consistent, raising into question how exactly the therapy improves sleep function. Is it overall muscle tone increases, a reduction in fatty deposits, or just awareness by the individual to maintain mouth-closure?

Another study compared myofunctional therapy and something called "passive" myofunctional therapy which consisted of a beaded device contained in the mouth during the night. They noted a major problem with compliance and myofunctional therapy, and that even objective results could be distorted due to high drop-out rates in studies. Their study preferred the "passive" device, but in reality, this is really an oral appliance (see prior section) and faces the same consideration of results on TMJ function and occlusion and does not really involve exercises besides the patient being instructed to "roll" the intra-oral bead at night [10].

My son and I are participating in a myofunctional therapy program for the past 6 months with a very engaging, thoughtful, and intelligent therapist named Sarah Hornsby RD, of Seattle, Washington. The excercises are varied and seem useful for strengthening the muscles of the lips and tongue. My favorite one involves lip strengthening by holding a weighted popsicle stick between the lips for 10 minute intervals. I feel like I had a lip "workout" with all of the usual soreness of classic weight-lifting but just on the lips. Another really positive one was to hold a plastic disk on the roof of the mouth while maintaining lip closure. With this as well, once could feel "the burn" on the lips. Finally, putting small rubber tubes under the upper and lower lips while maintaining closure for 5–10 minutes was also a very positive experience.

While my son's sleep seems subjectively fine now with almost no snoring and adequate rest, he also uses a supportive garment to keep his jaw closed at night, making for a very confounding variable. During the day, even with the exercises he

still seems to favor keeping his jaw open despite reminders, but not as much as before. We also are not super-compliant with the exercises. To me, the overall goal is to assist an individual in attaining the awareness and muscle strength to keep the jaw closed at all times or at least most of the time. It does not seem that despite tone improvement with myofunctional therapy, it is not necessarily a complete cure for mouth-breathing in the presence of an adequately breathing nose, but it seems very helpful! My overall view of myofunctional therapy after 6 months of treatment is that while it seems very helpful, it is very difficult to maintain compliance in a child. In a motivated adult, this is different, and results may be much better. The true benefit from myofunctional therapy appears to me to be the *awareness* and reflection upon the importance of converting one's self from a mouth-breathing to a nasal-breathing individual. It is this newfound awareness that needs to be near-constant that may be most critical for an individual to be more driven to maintain a closed mouth both by day and by night. Myofunctional therapy, with or without a mouth-closure device may be a useful complement to functional rhinoplasty in maintaining the nasal airway.

Facial Bone Expansion Strategies

As we had discussed in Chap. 4, as it seems likely that the root cause of obstructive sleep apnea and sleep disordered breathing is the progressive diminishment of the human maxilla and mandible, it stands to reason that strategies that focus on expanding the maxilla or mandible would reverse sleep apnea. While this is theoretically true, the answer in actual practice is not necessarily the case. As we have discussed, the airway causing sleep apnea is not simple airway narrowing, but instead may be more related to mouth-breathing related to nocturnal jaw slackening with subsequent unleashing of the relaxed tongue into the pharynx. Thus, even successful re-expansion of the maxilla and mandible does not necessarily translate into cessation of mouth-breathing and related sleep disorders.

That being said, there is abundantly clear evidence in the literature that variations of the maxillomandibular advancement procedure is highly effective in reducing the objective parameters of sleep-breathing disorders. A 2016 meta-analysis from Stanford University, in a group including the famed Guilleminault, Riley, and Powell analyzed 45 studies with individual data from 518 unique patients/interventions. The study showed: "Among patients for whom data were available, 197 of 268 (73.5%) had undergone prior surgery for OSA. Mean postoperative changes in the AHI and Respiratory Disturbance Index (RDI) after MMA were −47.8 (25.0) and −44.4 (33.0), respectively; mean (SE) reductions of AHI and RDI outcomes were 80.1% (1.8%) and 64.6% (4.0%), respectively; and 512 of 518 patients (98.8%) showed improvement. Significant improvements were also seen in the mean (SD) postoperative oxygen saturation nadir (70.1% [15.6%] to 87.0% [5.2%]; $P < .001$) and Epworth Sleepiness Scale score (13.5 [5.2] to 3.2 [3.2]; $P < .001$). Rates of surgical success and cure were 389 (85.5%) and 175 (38.5%), respectively, among

455 patients with AHI data and 44 (64.7%) and 13 (19.1%), respectively, among 68 patients with RDI data" [11].

Despite the efficacy of the procedure, it remains an unattractive option to most patients including myself. The invasiveness of any variation of the procedure involving osteotomies of the maxilla and mandible with permanent hardware fixation, airway support requirements including possible tracheotomy and maxilla-mandibular fixation (MMF) requirements, not even including the risk of actual surgical complications are almost all deal-breakers for most patients. In a study of 28 patients who had undergone maxilla-mandibular advancement, there was a total of 108 complications, 15 of which were major (requiring re-operation or admission). Interestingly, the authors listed the major complication rate at 13.9%, using major complications as the numerator and total complications as the denominator. Fifteen major complications in 28 patients is a 53.5% major complication rate, most of which were infections per the authors [12].

In this study, the authors also minimized the total complication rates by comparing the OSA MMA complications with a cohort of patients who had maxillo-mandibular advancement for non-OSA reasons, and tested statistical significance only *between the groups*, thus not mentioning the total complication rates that I re-calculated above.

As a rhinoplasty surgeon, one will also note an additional complication that is rarely discussed by even many maxilla-mandibular advancement surgeons: Secondary nasal/septal deviation. The etiology of this problem is not dissimilar to the common form of septal deviation as discussed in the previous chapters. In this case however, the septum remains in its original position, while the lower maxilla is advanced after LeFort osteotomy anteriorly. The upward sloping maxillary crest now exists in the midline spot that is currently occupied by the quadrangular cartilage. This causes the quadrangular septal cartilage to be displaced and buckle at its caudal end, even if released! (Fig. 9.2). As I said, this is not dissimilar to the bony/cartilaginous mismatch in developmental cases. In the Stanford University experience, this complication must be recognized, and expected to occur in 18.7% of cases, as they demonstrated in a retrospective study of 379 patients [13]. They did find a high level of surgical success (76.3% based on RDI criteria), and 71 patients underwent nasal surgery, including aesthetic nasal surgery. The authors provided excellent insight that patients must be counseled in advance about this problem's likelihood (subclinical cases may have a much higher incidence of postoperative septal deviation and valve compromise). Another excellent paper from a team in South Korea recommended a solution to this problem [14]. They advised that at the conclusion of the MMA, the septum be evaluated for deviation as well as the nasal valve. If abnormality is identified, the authors recommend resection of the caudal-most portion of the L-strut and including refinement of the nasal spine via an intra-oral upper lip vestibular approach. I do not disagree with this approach, but it can also be achieved via a transfixion incision as described in previous chapters. Either way, the problem should be addressed pro-actively as these authors recommend, and not after the patient develops nasal obstructive complaints, or develops worsened mouth-breathing or deviation-related aesthetics. I have seen several instances

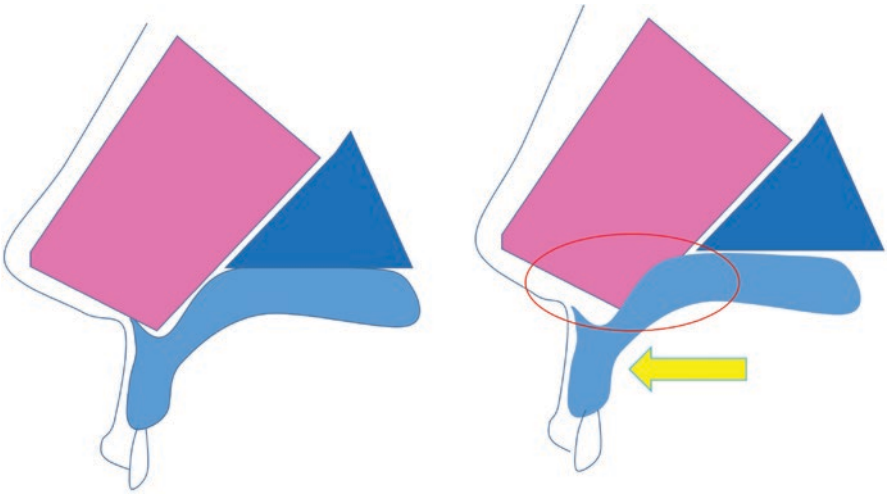

Fig. 9.2 Schematic of sagittal view of the nasal septum (pink) at its intersection with the maxilla (light blue) and with the vomer (dark blue). With LeFort I osteotomy and advancement of the maxillary segment (yellow arrow), even WITH complete release of the septum from the maxillary crest, will compete for space in the midline at the point encircled, and will create septal buckling with subsequent nasal breathing and discomfort. Do not confuse this for sinusitis

of patients who were not only surprised about their new nasal obstruction and deviation after MMA, but were told repeatedly that they simply had developed and were treated for "sinusitis." Of course the patients had evidence of inflammation of the maxillary sinuses, having them divided literally in half by the maxillary osteotomy, but the symptoms of nasal obstruction, pressure, congestion, and discharge is related to the newly deviated septum or perhaps a local reaction to hardware and osteotomy and is obviously not classic "sinusitis." This is not, unfortunately an isolated scenario but can be common where this procedure is performed commonly, and is almost always confused for sinusitis by the treating team, who frequently will refer for surgical treatment of this disorder. On a similar note, a similar line of thinking exists for infected dental implants, that providers can blame "sinusitis" instead of the obvious foreign implant that is triggering inflammation.

> Encouraging bony growth naturally: Reversal of "gracilization."
> Cryin' won't help you, prayin' won't do you no goodNow cryin' won't help you, prayin' won't do you no good
> Kansas Joe McCoy and Memphis Minnie in 1929, from "When the levee breaks"

As clinicians, we are generally taught to keep our patients happy and find solutions that sound palatable to them. After all, they are the client even if the insurance company may be the one actually paying you. So, we typically have some treatment options like a medication, or surgery that may have some upsides and downsides to offer, or maybe offer some unpleasant advice, but in general, we tend to avoid making life-altering pronouncements like in the quote above from a song popularized by Led Zeppelin. In the lyrics, the narrator is cautioning that the two easy options

(crying or praying) will not do the listener much good. Instead, only the option of moving remains. This is not dissimilar to the problem of the patient who expects the surgeon to fix their chronic problems with a simple procedure or the physician with a medication. Especially when these problems are chronic nasal disuse and mouth-breathing, neither surgical options nor medical options do too much help in the long run. In my opinion, the best long-term option to reverse these problems is to encourage musculoskeletal tone via extensive exercise and avoidance of sedentarism, a generally healthy diet without excessive consumption of food, and high quality and sufficient sleep. This can be applicable to all age groups, from toddlers to the elderly.

As we discussed in a previous chapter how perhaps the most important cause of human facial diminishment is the process of "gracilization." Gracilization is the reduction of bone thickness and muscle tone over the course of human history, as technological advances has resulted in less requirements for extensive physical exertion to gather and prepare food. These advances include the development of fire for processing food for easier digestion, agriculture for easier gathering, and even blenders, which make food easier for chewing. Chirchir (2015) studied "peripheral quantitative CT and microtomography to measure trabecular bone of limb epiphyses (long bone articular ends) in modern humans and chimpanzees and in fossil hominins attributed to *Australopithecus africanus*, *Paranthropus robustus*/early *Homo* from Swartkrans, *Homo neanderthalensis*, and early Homo sapiens." They found that evidence that "the low trabecular density of the recent modern human skeleton evolved late in our evolutionary history, potentially resulting from increased sedentarism and reliance on technological and cultural innovations" [15].

Further, Ryan and Shaw showed in another comparative anatomy study that this gracilization or weakening of the skeleton is due to decreased biomechanical loading. Their study sampled femur Computed Tomography (CT) scans of 229 individuals from multiple primate species, and 59 individuals from distinct archaeological human populations. They showed that foraging human populations had bone thickness more similar in structure to wild non-human primates of similar size [16]. Other authors have confirmed that our recent and distant ancestors had more robust skeletons due to increased physical activity requirements [17].

While these studies focus upon long bones, the facial bones could follow a similar trajectory and can be related to masticatory loading or even an overall activity level. A comparative study of chimp masseter muscles disclosed that "Powerful masticatory muscles are found in most primates; contrarily, in both modern and fossil member Homo, these muscles are considerably smaller. The evolving hominid masticatory apparatus shifted towards a pattern of gracilization nearly simultaneously with accelerated encephalization in early *Homo sapiens*" [18].

So, what is the unpleasant answer to the patient asking for the easy solution? The gracilization process must be reversed, from birth to death. That means seriously increased exercise requirements and severe reductions in sedentarism and poor diet. Through near-constant physical activity, the thinning of our bones, possibly including our diminished maxilla and mandible bones can be reversed, possibly including a diet of less processed foods. This is hard, particularly in the modern world of cubicles, constant WIFI connectivity, and fast food. It is much easier to sit and

watch Netflix or catchup on Facebook or Instagram. But as Memphis Minnie and Kansas Joe McCoy remind us, crying or praying isn't going to be of much help here. Many of the problems described in the previous chapters can be reversed simply through intense exercise and a healthy diet.

Studies have shown that "exercise regimes combining resistance and impact training should provide larger bone response than either one of them alone in growing children" [19]. Further, "mechanical loading is a major regulator of bone mass and geometry. The osteocytes network is considered the main sensor of loads, through the shear stress generated by strain induced fluid flow in the lacuno-canalicular system. Intracellular transduction implies several kinases and phosphorylation of the estrogen receptor. Several extra-cellular mediators, among which NO and prostaglandins are transducing the signal to the effector cells. Disuse results in osteocytes apoptosis and rapid imbalanced bone resorption, leading to severe osteoporosis. Exercising during growth increases peak bone mass and could be beneficial with regards to osteoporosis later in life, but the gain could be lost if training is abandoned [20].

Finally, a study showed that increases in bone density and strength followed increases in muscle mass during the pubertal growth spurt. They described the "mechanostat" theory, that these increases in bone strength are specifically due to increased loads "imposed" by muscle forces. Gain in lean body mass (a surrogate for muscle bulk) preceded bone mineral content increases by over half a year in males and females. While the authors acknowledged that this muscle growth preceding bony growth could be genetically determined, they felt it was more likely that the bone strength increases were resultant to the increase in muscle loading [21].

While this may not have perfect translation to the maxilla and mandible, and these bones may be just as much effected by occlusal loading as systemic exercise loading, one cannot help but observe that the most active and athletic individuals also frequently have associated adequate facial structure [22].

Perhaps the exercise causes the facial growth, or the good sleep quality permits more and higher quality exercise, or perhaps there is a feedback loop that has not been discovered. Either way, my own pre-pubertal children are encouraged to have as extensive high impact exercise as possible. This is achieved through participation in contact sports, (where my personal belief is that the benefits outweigh the risks, in contrast to conventional modern wisdom), hiking, swimming, and anything else we can think of. Of course, the outcome is not able to prove anything one way or another, but I feel it is my personal duty to push as much exercise at this stage and beyond as possible while they are in my care. As Nicholas Taleb's "anti-fragile" concept extolls, physical stressors like heavy exercise has the potential to be protective against actual hazards, unlike an over-protective strategy to avoid and stress or conflict for one's offspring that may have resulted in modern "gracilization" [23]. How well this strategy will work still remains to be seen. On a strenuous hike up Mount Mansfield in Vermont, all three of my children informed me that they hate me and that I am a horrible person. Fortunately, by lunchtime, they seemed to have forgotten this animosity, and I continue to hope that the fresh air and physical stress of the hike will yield health benefits.

Why does this not translate much into patient care? The answer may be found in game theory's "prisoner's dilemma" model, according to a brilliant 2004 study: Essentially, in this scenario, the patient and clinician are opponents in a simple game, where a patient with poor lifestyle choices that has resulted in medical problems now visits a physician in consultation. The physician can choose to offer the "easy" answer to their problem (pills or surgery), which can improve symptoms temporarily, but will not address the root cause, or permit a permanent solution, or the "hard" solution of changing lifestyle completely with a long discussion and counseling. The health-care model rewards the physician for taking the easy route financially for procedures and a short visit. The patient, likewise, can choose to seek the easy or hard solution, the easy one being more favorable to the patient who has had a lifetime of poor health choices. Only when the physician and patient cooperate to choose the "hard" solution, going against their own internal short-term reward pathways, can the patient truly recover [24]. Essentially, only the shared goal of becoming better people will motivate both parties to purposely seek the hard answer. In the current culture of our western world, this is not common. While this may be too late for my generation and its predecessors, perhaps the future generations will seek this type of enlightenment not found in most medical clinics today. In the current Covid-19 era, this game theory failure by both parties may be at least partially responsible for the severity experienced by the least healthy patients (see Chap. 10 and appendix).

Functional appliances for jaw expansion:

Q: What do I think of the efficacy of functional intra-oral appliances?
A: I remain both optimistic and skeptical about the utility of these devices and do not have enough practical information to decide.

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