Comparing The Ergogenic Effects of Mouth Guards

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COMPARING THE ERGOGENIC EFFECTS OF MOUTH GUARDS

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28 March 2016

Submitted in partial fulfillment of the requirements for graduation with Honors

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Abstract

Many studies have looked into the ergogenic effect of wearing an oral appliance such as a mandibular orthopedic repositioning appliance or mouth guard. Little research has been done comparing the performance enhancing qualities of different types of mouth guards. In this study sixteen participants were tested on their grip strengths with a hand dynamometer under four different conditions. These conditions included mouth open, mouth closed, clenching on a generic boil and bite mouth guard, and clenching on the Under Armour ArmourBite® mouth guard. The grip strength results were analyzed and showed a significant increase in grip strength from the mouth closed condition to the Under Armour condition. The boil and bite mouth guard did not cause any significant improvement in grip strength from the mouth closed condition. The Under Armour mouth guard moves the mandible anterior and inferior to its natural position. This change in jaw posture seems to have a positive effect on grip strength results. Panoramic dental x-rays were also taken for each condition in order to analyze the interocclusal space. These x-rays showed that the Under Armour condition caused a significantly greater interocclusal space than the generic boil and bite. Future studies should continue to focus on looking into what causes these ergogenic effects, as well as what jaw and occlusion parameters optimize the ergogenic effect.
COMPARING THE ERGOGENIC EFFECTS OF MOUTH GUARDS

In today’s environment, the world of athletics is as competitive as it has ever been. Technological advancements in multiple fields have left athletes looking for every possible advantage to improve their performance. This is especially true in the field of athletic equipment. Continued advancements in technology have lead to an influx of athletic equipment aimed at improving an athlete’s preparation, performance, and/or recovery. A piece of equipment that has been commonplace in many athletes’ lockers, the mouth guard, has for many years been implicated as having some type of ergogenic effect (Gelb, Mehta, & Forgione, 1996). Recently, a major company in sports performance equipment, Under Armour, recognized the market for a mouth guard that can properly protect the dentition of the athlete, while also improving performance. This is the basis behind Under Armour’s Performance Mouthwear™ line of products. They developed these products after partnering with Bite Tech, a company based in Minneapolis that develops oral devices. The main technology behind the product line has been termed ArmourBite® and is patented by Bite Tech. The companies claim that: “UA Performance Mouthwear can help any athlete improve strength, endurance and reaction time, reduce athletic stress, and with the mouthguard, reduce impact from blows to the jaw” (“Bite Tech,” 2009).

There are several research studies that support this technology. These studies focus on a variety of areas involved in performance enhancement. Dr. Dena Garner, a professor at The Citadel, is one of the leading researchers in the area of mouth guards and their ergogenic effects. Her studies focus on the ability of a mouthpiece to improve reaction times (Garner & Miskimin, 2009), improve lactate levels (Garner & McDivitt, 2009), reduce cortisol levels (Garner, Dudgeon, & McDivitt, 2011), and improve gas exchange parameters (Garner, Dudgeon, Scheett, & McDivitt, 2011). Some similarities between all of these studies are that they all investigate
endurance factors rather than strength, and they all use only one type of mouthpiece (a Bite Tech mouthpiece) in each study. Other researchers have investigated an oral device’s effect on strength factors, however there is very little research comparing multiple types of mouthpieces. This leaves the door open for the following research, which compares differences in grip strength with subjects biting down on a generic boil and bite mouth guard, versus subjects biting down on an ArmourBite® mouth guard. Based on previous studies, it is hypothesized that the Under Armour mouth guard will show a greater increase in grip strength than the generic boil and bite mouth guard.

Literature Review

*Temporomandibular Joint*

The jaw includes the mandible and the maxilla. The mandible is the movable part of the jaw and has no bony attachment connecting it to the rest of the skull. Instead, the mandible is connected to the rest of the skull through a series of muscles, ligaments, and other soft tissues fixated around the temporomandibular joint (TMJ). The TMJ is “certainly one of the most complex joints in the body” (Okeson, 2013). The joint is formed from the mandibular condyle and the mandibular fossa of the temporal bone. Although technically the joint is only made up of two bones (the mandible and the temporal bone), it is classified as a compound joint. This classification is allowed due to a nonossified bone called the articular disk. The disk is situated between the mandibular condyle and the mandibular fossa. It is flexible and can adapt its shape slightly in order to meet the complex movement demands of the joint. These movements can include both hinging movements as well as gliding movements, both necessary for mastication. The TMJ is a synovial joint with three functional ligaments that support the articulation of the
articular disk, the condyle, and the fossa. The groups of muscles that cause movement of the TMJ are referred to as the muscles of mastication.

Although the muscles of mastication are directly implicated in the movement of the mandible, there are many other muscles that contribute to the complex motions involved with the head, neck, and jaw. The functions and contractions of many of these muscles are intertwined into one large system always working as a unit. With this in mind, it is understandable to think that modifications to the TMJ could have an effect on many other parts of the body, such as the forearm muscles that control grip strength. This can best be described by Dr. Jeffrey Okeson:

It can be quickly observed that the study of mandibular function is not limited to the muscles of mastication. Other major muscles, such as the sternocleidomastoid and the posterior cervical muscles, play major roles in stabilizing the skull and enabling controlled movements of the mandible to be performed. There is a finely tuned dynamic balance among all of the head and neck muscles; this must be appreciated if the physiology of mandibular movements is to be understood…. With an understanding of this relationship, one can see that any effect on the function of the muscles of mastication also has an effect on other muscles of the head and neck (Okeson, 2013).

**Historical Overview**

Research on the ergogenic effect of oral devices has been ongoing since Dr. John Stenger, Notre Dame football’s team dentist, noted a possible increase in strength amongst his athletes while they were wearing mouthpieces in the 1970s (Gelb et al., 1996). Dr. Stephen Smith was one of the first to research and write about this possible increase in strength. In 1978 he conducted research on several professional football players and concluded that, “there was a
correlation between the corrected jaw posture and the ability to give a stronger contraction” (Gelb et al., 1996). In Smith’s experiment he measured the athletes’ isometric strength related to the deltoid press under three different conditions. These conditions included that of natural occlusion, jaw position from an unadjusted football mouth guard, and a wax bite position meant to position the subject’s jaw to match that of the closest speaking space. “The closest speaking space (CSS) is the minimal distance in the teeth that occurs during the pronunciation of words containing sibilant sounds, particularly those in combination with the vowels /e/ and /i/” (Sakar, Bural, Sulun, Oztas, & Marsan, 2013). Smith claimed that there was a correlation between corrected jaw posture and the ability to give a stronger contraction. However, his results were criticized for not being subjected to proper statistical analysis. In 1991, Forgione, Mehta, and Westcott performed a statistical analysis on Smith’s results and came to a similar conclusion as Smith. The analysis showed that the subjects with the unadjusted football mouth guards produced a greater contraction than those with natural occlusion, and that subjects with the wax bite set at CSS produced a greater contraction than those with the football mouth guards (Forgione et al., 1991). Although the statistical analysis was not completed for several years, Smith’s research offered a framework for other researchers to look into the idea of a certain jaw position creating the conditions for optimal muscular contraction.

In 1983 researchers published an article in *The Journal of Prosthetic Dentistry* looking at the effects of various mandibular positions on appendage muscle strength (Williams, Chaconas, & Bader, 1983). This research tested subjects in three different conditions: centric occlusion (condition 1), supported resting occlusion (condition 2), and an appliance that gave an additional 5mm to the vertical dimension of occlusion (condition 3). Condition 1 is simply a patient clenching their teeth with no obstruction. Condition 2 was determined by a variety of parameters
including an interocclusal space similar to that of the CSS of each patient. Condition 3 was determined by an increase in the vertical dimension of occlusion by 5mm from the supported resting position. It is important to note that the vertical dimension of occlusion refers to the height of the face during maximum occlusion. Therefore, condition 3 would have resulted in a 5mm increase in interocclusal space from condition 2. The results showed that the supported natural occlusion (condition 2) allowed for the greatest strength in all four appendages. These results show that continuously increasing vertical occlusion may not be the key to increasing muscular strength, considering the 5mm vertical occlusion did not allow for the greatest strength results. However, the results do show that the insertion of an oral appliance that simply supports resting occlusion has an effect of increasing the strength of all four appendages. When these results are combined with Dr. Smith’s, it may be viable that there is an optimal interocclusal distance for strength enhancement. This distance could be related to the interocclusal space measured at the closest speaking space. This distance can vary from patient to patient, but is thought to be typically around 2.27 ± 1.17mm (Sakar et al., 2013).

**Modern Equipment and Research**

More recent studies have also found a positive correlation between oral appliances and performance enhancement. For the majority of these studies, the oral device tested is referred to as a mandibular orthopedic repositioning appliance (MORA). It is important to note that MORAs are not consistent throughout these studies. MORAs are dental appliances that are typically used to treat TMJ disorders. Most MORAs increase the vertical dimension of occlusion, and move the mandible more anterior than its resting position. However, there is no consistent set of measurements that all MORAs are subject to, so these changes in jaw positioning are typically specified in each study. In 2013, a study found that subjects had increased trunk and upper limb
muscle activation while wearing a MORA (Lee, Hong, Park, & Choi, 2013). Another study tested the effect of wearing a MORA on the grip strength of subjects. This study showed that wearing a MORA had caused a significant increase in the grip strength of the subjects (Lee et al., 2014). Other studies have also found a correlation between teeth clenching and enhanced muscle activity (Garceau, Petushek, Fauth, & Ebben, 2010; Kawakubo et al., 2013; Yamanaka et al., 2000).

Many studies have looked at clenching with or without an oral appliance on other factors than just strength and muscle activity. One study has shown that clenching without an oral appliance allowed subjects to reach their peak force more quickly in the countermovement jump (Ebben, Flanagan, & Jensen, 2008). Visual and auditory reaction times have also been shown to improve while wearing an oral appliance such as a mouthpiece (Garner & Miskimin, 2009). Changes in cortisol levels during resistance training have been shown while wearing a mouthpiece versus no mouthpiece (Garner, Dudgeon, & McDivitt, 2011). Several studies have looked into the possible effects wearing a mouthpiece could have on respiratory and gas exchange factors. One study showed that wearing a mouthpiece can improve gas exchange parameters including voluntary oxygen consumption, and voluntary carbon dioxide production (Garner, Dudgeon, Scheet, & McDivitt, 2011). Another study has shown that wearing an oral device can improve anaerobic ability and increase forced expiratory volume (Morales, Busca, Solana-Tramunt, & Miro, 2015). Ringhof even showed that clenching the jaw can cause improved posture control (Ringhof, Leibold, Hellmann, & Stein, 2015). Clearly, many aspects of performance enhancement have been tested as they relate to clenching the jaw with or without an oral device.
Many articles have been cited by Bite Tech and Under Armour supporting ArmourBite® technology. (Alexander, 1999; Bowen et al., 2009; Garner, Dudgeon, & McDivitt, 2011; Garner, Dudgeon, Scheet, & McDivitt, 2011; Garner & McDivitt, 2009; Garner & Miskimin, 2009; House & Wishmyer, 2011). These studies all show some type of improved performance while wearing a Bite Tech mouthpiece versus no oral device. However, none of them compare the Bite Tech mouthpiece with another type of mouthpiece or oral device. This is a key deficiency in the research, for it may be possible that another oral device could produce the same results. There is a significant lack of research on the topic as a whole that compares the performance enhancing aspects of different types of mouthpieces. The study performed for this paper is one of very few that satisfies the need for these types of comparisons, and therefore has significance for the literature in the field.

Methods

Subjects were gathered through an email request sent to the entire football team at Otterbein University. The first twenty students to respond to the email were used as the subjects in this study. Four of the subjects were absent on the day of testing, therefore a total of sixteen subjects were used in the study. All subjects were healthy male student athletes between the ages of 18 and 22. Prior to participating, all subjects were given a description of the study and gave their consent to participate. They were all under the understanding that they could remove themselves from participating at any time during the study. The subjects were asked if they had been diagnosed with any TMJ disorders, and if they had any injuries that would affect their grip strength. For all subjects, the answer to each of these questions was no. The subjects were each given an Under Armour ArmourBite® mouth guard (see figure 1) and a red boil and bite mouth guard (see figure 2) provided by the athletic training staff. Both mouth guards were fitted using
the fitting specifications given in the instructions for the Under Armour mouth guard. This process involved placing the mouth guard in boiling water, and then biting down on the soft material as it cools and hardens around the dentition of the subject.

Once the fitting was completed, the subjects were instructed to grip a hand dynamometer (see figure 3) under four different conditions in order to test their grip strength. Grip strength was used in order to remain consistent with many of the previous studies. It has been shown to be one of the most frequently used tests in research involving strength, and is a simple test to perform (Roberts et al., 2011). The dynamometer was set to the second grip position for each subject and each condition to remain consistent throughout the testing. The second grip position is the most frequently used, and is considered the most reliable and consistent position (Roberts et al., 2011). Condition 1 was with the subject’s mouth open, and will be referred to as OPEN (see figure 4). Condition 2 was maximum occlusion without any oral appliance, and will be referred to as CLOSED (see figure 5). Condition 3 was maximum occlusion with the red boil and bite mouth guard, and will be referred to as B&B (see figure 6). Condition 4 was maximum occlusion with the Under Armour ArmourBite® mouth guard, and will be referred to as UA (see figure 7). For each condition the subjects were instructed to grip the dynamometer as hard as they could for three seconds. The subjects were tested with their dominant hand. They were tested while standing, with the elbow of their testing arm bent at 90 degrees, and the other arm resting at their
side. The maximum force exerted on the instrument during the three seconds was observed and recorded for each condition. Ten of the subjects (Group 1) were tested under each condition consecutively, in random order, and with minimum rest between conditions. After analysis of this data, it was observed that fatigue may have been a factor in the results. Therefore, another group of 6 subjects (Group 2) were tested under each condition with approximately five minutes of rest between each test.

Figure 4: Condition OPEN

Figure 5: Condition CLOSED

Figure 6: Condition B&B

Figure 7: Condition UA
Results

The raw data for the grip strength tests were recorded in kilograms and are found in the first table of appendix A. The results were broken down by condition, and were included for both groups. The aspect of the data that was analyzed was the change in grip strength between the various conditions. The results comparing the OPEN and CLOSED conditions can be found in the second table of appendix A. Averages were taken for both groups, as well as for the total which combined the data from both groups. Standard deviations were calculated, and a p-value was calculated for each average using a paired, one tailed t-test. The third table in appendix A shows the average changes in grip strength from the CLOSED condition to the B&B condition, as well as from the CLOSED condition to the UA condition.

Many other studies have shown that clenching the teeth, even with no oral appliance, has an effect of increasing muscle activity and strength (Yamanaka et al., 2000) (Kawakubo et al., 2013) (Garceau et al., 2010). In this study the combined values for each group show an increase in grip strength from conditions OPEN to CLOSED. However, after proper statistical analysis the results were not able to show a significant difference in grip strength between the OPEN and CLOSED conditions (p-value = 0.12). This is most likely due to the breaking up of the subjects into the two groups. The data for Group 1 was very sporadic, presumably due to the fatigue, as Group 1 was not given proper rest between tests. The random order of the tests, along with the input of fatigue, resulted in a wide range of varied results for Group 1. When analyzing the two groups separately, the statistical analysis shows that Group 2 showed more consistent changes than Group 1. For the changes between OPEN and CLOSED, Group 1 showed insignificant changes in their grip strength due to a very high p-value of 0.48. However, Group 2 did show a
ERGOGENIC EFFECT OF MOUTH GUARDS

significant increase in grip strength in the CLOSED condition due to a much lower p-value of .02. This would allow one to believe that fatigue played a strong role in Group 1, and if all of the subjects would have been given proper rest such as those in Group 2, the total results may have proven to show a more significant increase in grip strength for condition CLOSED.

Conditions B&B and UA were both compared to the CLOSED condition. The purpose was to see if the B&B and the UA condition caused any change in grip strength from CLOSED. The results showed that there was not a significant change in grip strength for the B&B condition compared to the CLOSED condition. Although the average values showed an increase in grip strength for the B&B condition, the p-value for these averages was 0.07, indicating an insignificant change. Group 1 and Group 2 both showed insignificant values for the change in grip strength between the B&B and the CLOSED conditions. Group 2 had a more significant value p-value (0.08) than Group 1 (0.14) showing that fatigue still may have played a factor into the results. However, the fact that Group 2 showed an improved significance, yet still did not have a significant p-value indicates the B&B condition does not offer improved grip strength over the CLOSED condition. Results for the UA condition, on the other hand, did show a significant increase in grip strength over the CLOSED condition. Under condition UA, Group 1 showed an increase in grip strength with a significant p-value (0.03). Group 2 also showed an increase in grip strength with a p-value (0.0007) much lower than Group 1. These significance values show that the fatigue still played a factor in the two groups even though both groups showed significant results. When data from both groups was analyzed for the UA condition, it was shown that grip strength was significantly (p-value = 0.003) increased by roughly 3 kilograms more than the CLOSED condition. These results show that the ArmourBite® mouth guard caused a significant increase in grip strength for healthy male student athletes.
Discussion

Looking back on the methods for this study, it would have been better if all subjects were tested with proper rest between each test. Splitting the subjects into two groups was not ideal. The results from Group 2 consistently had lower p-values, and therefore were more significant than the results from Group 1. If all subjects were tested with proper rest like those from Group 2, it is believed that the total results for the study would have proved more significant. Another limitation for this study was the possible impact of the placebo effect. In order to eliminate the placebo effect from this study, the subjects would need to be given an oral device that they would have no effect on the subject’s bite. This would cause the subject to think that the device in their mouth may be helping, however the device would still maintain the same bite as during condition CLOSED. A placebo device like this could possibly be made by taking an impression of the subjects mouth and fabricating a custom mouthpiece with a very thin material. Although there were limitations to the study, the fact that Group 1, Group 2, and the total results all showed significant increases in grip strength while under condition UA shows that the ArmourBite® mouth guard certainly does have an ergogenic effect. One of the more interesting questions that still needs to be answered through more research is why this effect is seen.

Many authors claim that the results are due to a physiological phenomena termed concurrent activation potentiation (CAP) (Garceau et al., 2010) (Ebben et al., 2008). CAP is the theory that a remote voluntary contraction simultaneous to the contraction of the prime mover muscle may allow for a more forceful contraction (Ebben, 2006). For example, in this study activating the muscles in one’s neck and jaw may allow for a more forceful contraction of the forearm muscles used for grip strength. The results in this study did not show that CAP was a major factor in the grip strength of the subjects. If CAP were the major factor leading to more
forceful contraction, one would think that condition CLOSED would have resulted in greater
grip strength values than condition OPEN. The results in this study showed no significant
increase in grip strength from condition OPEN to CLOSED. However, this may have been due to
the fatigue of the subjects in Group 1. A future study where all subjects are given proper rest time
between tests should be done to show if CAP plays a role in increasing grip strength.

Some authors claim that the ergogenic effect is due to the realigning of the TMJ. This is
more inline with the results of this study, as this is the basis behind Bite Tech’s ArmourBite®
technology. Therefore, if this were the major physiological factor behind the ergogenic effects, it
would make sense that the UA condition showed a significant increase in grip strength over the
CLOSED condition. Bite Tech’s mouth guards are aimed at moving the mandible slightly
anterior and inferior to its natural position. This places the mandibular condyle into a more
natural position in the mandibular fossa, and presumably alleviates some of the pressure the
condyle puts on the fossa during clenching. Dr. Dena Garner has shown that this also has the
effect of creating a larger airway opening of the oropharynx (Garner et al., 2009). She has done
many other studies that suggest possible reasons for the ergogenic effect of Bite Tech mouth
guards. She has proposed that lowered lactate levels (Garner et al., 2009), as well as changes in
cortisol levels (Garner et al., 2011) may be possible mechanisms for the ergogenic effects.

Along with the realignment of the TMJ is a change in the occlusion parameters of the
subject. For this study, panoramic dental x-rays were taken for to analyze conditions CLOSED,
B&B, and UA (see appendix B). The interocclusal space for each condition was analyzed to see
if there was a difference in the occlusal parameters between conditions UA and B&B. The
analysis showed that the UA condition caused for a significant increase in the interocclusal space
over condition B&B. Further analysis of the interocclusal space of condition UA should be done
in order to see if it is similar to the CSS. This would show if this study supports others (Smith, 1978) (Williams et al., 1983) (Forgione et al., 1991) (Gelb et al., 1996), in the idea that having occlusion parameters similar to those of the CSS may improve certain performance enhancement factors. These results along with other literature would lead one to speculate that the optimal jaw positioning may involve moving the mandibular fossa both slightly anterior and inferior. Further research must be done to confirm if interoclussal space plays a significant factor in the ergogenic effects. Further studies must be done to look into other possible mechanisms as to why these ergogenic effects are seen. Other future studies should aim to look more into the optimal jaw position and occlusion parameters to maximize these ergogenic effects.
References


Appendix A

<table>
<thead>
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<th>Strength Data In kilograms</th>
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<tbody>
<tr>
<td>OPEN</td>
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Mean Increases from OPEN to CLOSED in Kilograms w/ Standard Deviations and P-Values

<table>
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<td>Group 1</td>
<td>0.1 ± 5.6 (0.48)</td>
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<tr>
<td>Group 2</td>
<td>4.3 ± 3.7 (0.02)</td>
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<tr>
<td>Total</td>
<td>1.7 ± 5.3 (0.12)</td>
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Mean Increases from CLOSED in Kilograms w/ Standard Deviations and P-Values

<table>
<thead>
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<th>B&amp;B</th>
<th>UA</th>
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<tr>
<td>Group 1</td>
<td>2.4 ± 6.5 (0.14)</td>
<td>3.3 ± 4.9 (0.03)</td>
</tr>
<tr>
<td>Group 2</td>
<td>1.3 ± 2.1 (0.08)</td>
<td>2.7 ± 1.0 (0.00)</td>
</tr>
<tr>
<td>Total</td>
<td>2.0 ± 5.2 (0.07)</td>
<td>3.1 ± 3.9 (0.00)</td>
</tr>
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</table>
Appendix B

Panoramic dental x-ray at maximum occlusion with no oral device, representing condition CLOSED.

Panoramic dental x-ray of condition B&B. Interoclussal space was roughly measured to be less than that of UA, but greater than CLOSED.
Panoramic dental x-ray of condition UA. Interocclusal space was measured to be greater than that of condition B&B.