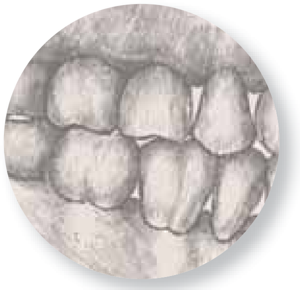

Avoidance Behavior to Minuscule Iatrogenically Applied Occlusal Interferences: A Pilot Study

L. Parnell Taylor, DDS; Dahye Sung, DDS; Theresa T. Nguyen, DDS; and Carol V. Stockhausen, DDS

ABSTRACT The physiology of the masticatory system continuously seeks homeostasis. This is achieved via the protective neuromuscular guidance system. Hence, a single premature occlusal interference, even as thin as 8–60 µm, could cause adverse jaw positioning. In this study, iatrogenic interferences much less than 50 µm were added to an occlusal stop of tooth No. 30 and to a nonoccluding cusp on tooth No. 19 that served as an internal control. The results from this proof-of-concept study demonstrated mandibular avoidance behaviors when these interferences were created ($p < 0.001$).

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Conflict of Interest Disclosure: None reported.

Sletten[1] asserted that an iatrogenically and intentionally created occlusal interference as thin as 5–10 µm could cause a mandibular neuromuscular avoidance by shifting away from the interference.

A co-author, Dumont, performed an informal test on some of his bioaesthetic maxillary anterior-guided orthosis (BMAGO) patients who had demonstrated even occlusal contacts with seated stable condylar positions (SCCP). Over the years, he had observed a strong correlation of early canine tooth wear to occurring on the contralateral side of an observed centric relation interference.[2] He wanted to test the hypothesis that premature centric interferences cause protective avoidance behaviors on the contralateral side. His test is as follows.

Occlusal stops were marked using Mylar articulating tape in maximum occlusal contact. Bonding agent was applied, air thinned and polymerized over the occlusal stop of the mesial buccal cusp of tooth No. 30. This was done on a precisely adjusted and stabilized BMAGO. Initially, these patients identified the stop precisely at the No. 30 position. Within 10–15 minutes these patients indicated the prematurity had shifted to the position of tooth No. 22.

This demonstration begs the questions: How does this information impact dentistry as it relates to our current literature and practice protocols? Is it important in restorative dentistry, occlusion, TMD and orthodontics that a 10–50 µm interference can potentially influence an otherwise well-functioning system?

It occurred to the current authors that a small proof-of-concept study could be performed on several patients to test this occlusal avoidance behavior.

A review of literature was performed systematically utilizing a critically appraised topic (CAT) to apply evidence-based dentistry (EBD) to this area of interest.[3] The population, intervention, comparison/outcome, time (PICOT) question asked was: "How does the process of neuromuscular avoidance affect a person's occlusion and how much of a force differential is needed in order to cause neuromuscular avoidance?" Keywords used in the search were "neuromuscular avoidance," "occlusal interferences" and "stomatognathic system."

The best evidence/references search yielded three citations that talked about the minimum tactile threshold needed to detect interference interocclusally. None discussed the long-term possible effects of maintaining subtle minimal interfering thicknesses.

One study compared bruxers to nonbruxers. These patients were able to detect 17.9 μm and 29.9 μm respectively[4] Another study demonstrated the minimum detectable thickness to be 200 μm. However, this paper studied the effects of speed of closure.[5] The third paper studied gender comparisons with bruxism and the minimum interdental threshold of detection. The minimum detectable thickness averaged 14.5 μm.[6]

Three other studies found in the literature review demonstrated interocclusal detection thresholds that ranged from 8–60 μm.[7–9]

None of these aforementioned studies commented on what happened after a period of time with these interferences.

In 1976, Blankenship and Ramfjord[10] placed cast gold splints on five adult female rhesus monkeys. They intentionally (and pathologically) shifted the animals' mandibles 3–4 mm to the right. They were all sacrificed at 2.5 weeks, six, 6.5 and nine months, with the exception of one who died on its own from likely starvation from refusing to eat at 4.5 months. All lost weight until they started gaining weight again and eating their regular food at six months. Postmortem exams demonstrated condylar neck changes and not condylar changes to the "inflicted pathology."

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In another paper, Ramfjord and Blankenship[11] increased the vertical dimension of occlusion by 7 mm on five adult male rhesus monkeys. They added cast overlays to the posterior teeth with nothing being done to the anteriors. It should come as no surprise that, without anterior tooth coupling, the posterior teeth intruded and the anterior teeth super-erupted. While the monkeys' dental systems showed some recovery toward pretest conditions once the overlays were removed, they did not completely rectify themselves prior to sacrificing the animals.

Hannam et al.[12] applied a computer model to hemisected mandibles analyzing vectors the muscles applied to mandibular movement. Future studies applying this knowledge might be informative in identifying muscle movements in response to interferences of dentate individuals.

Another study by Ho et al.[13] observed what happens at the bone-periodontal ligament (PDL)-tooth interface when loads are applied to teeth from a cellular and molecular level. Ho affirms, "… anatomical axis and loading axis should coincide for the physiological function of the joint … ." Further, Ho says, "… if eccentric loading perpetuates, joint (PDL) impairment is inevitable."

Tilliss et al.[14] noted that sealants being placed should have occlusion checked and adjusted postplacement because most patients were unable to self-adjust the interference.

This pilot study was designed as a proof of concept to test the feasibility of studying the effects of miniscule occlusal interference on adults. As evidenced by Sletten et al.[1] as well as Taylor et al.,[15] subtle occlusal discrepancies consistently shift occlusal perception to the anterior teeth.

The hypothesis of this study was: Thin occlusal interferences will cause a neuromuscular response by shifting patient awareness away from the hyperocclusal contacts within a specific time period (15 minutes). The corollary null hypothesis was: A thin interference will not affect occlusal contact in dentitions of the patients studied for a specific time period.

Methods

To perform this study, the author mentored three third-year dental students as part of their research requirements.

After obtaining Institutional Review Board approval (IRB #HE5140282), 29 adult subjects from the school of dentistry volunteered to participate in the study. Patient age was not an inclusion or exclusion criteria. Patient selection was not performed with any specific criteria for occlusal scheme, stability of TM joints and first point of contact in maximal intercuspal position (MIP) other than the presence

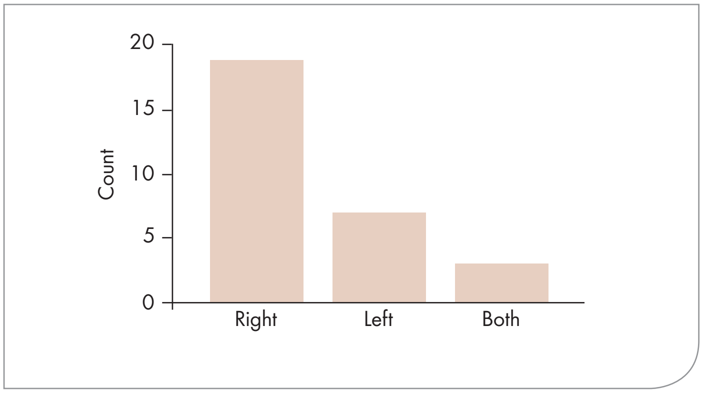

FIGURE 1. Immediate post-test response.

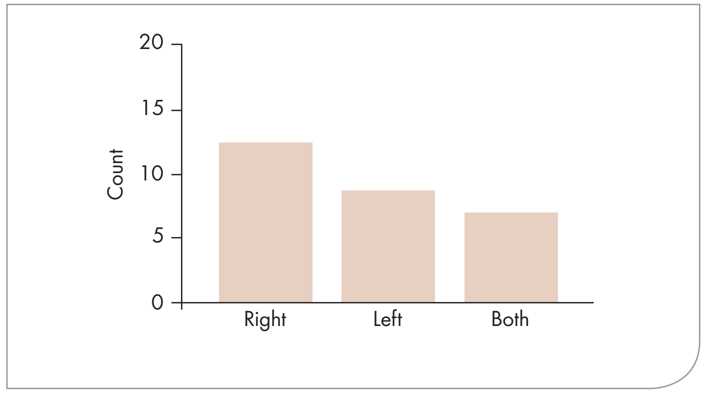

FIGURE 2. Fifteen minutes post test.

of all natural teeth at least to the second molars. No attempt was made to stabilize the subjects' occlusions before the study.

A short interview was conducted in the pre- and post-test employing confounding questions. The patients were asked about the tastes, smells, speech and breathing issues they might have had at the beginning and end of the testing. This interview was conducted to distract the patients from the main question, "Where do your teeth touch first?"

Patients were then tested. A Mylar occlusal marking tape was used to mark the patient's first point of contact, identifying occlusal stops. A thin layer of bonding agent mixed with an extremely small amount of cavity detection dye was applied to the occlusal stop on tooth No. 30, air thinned and then polymerized. The application of the dye to the bonding agent allowed clear visualization of the placement position. The same process was accomplished on the contralateral molar, tooth No. 19. However, the bonding agent was applied to a nonoccluding cusp for tooth No. 19. The addition of the green dye, mixed into the bonding agent, made it possible to visually overthin the bonding agent well beyond the 50+ μm recommended by the manufacturer. It also made it easy to remove it once the tests were completed.

It should be noted that a separate calibration session was completed in order to achieve interoperator reliability in applying the bonding agent.

By simultaneously applying bonding agent to both the occluding cusps and nonoccluding cusps, the investigators effectively created internal controls making the patient unaware of which cusps had the occlusal interference. This was to negate the need for "sham patients" in the study to serve as an external control.

Immediately after application, subjects were again interviewed. They were also asked, again, to inform the investigators where they perceived the first occlusal contact (right side, left side or both sides simultaneously). This location was recorded. Fifteen minutes later, the same interview was repeated. The first occlusal contact was then again recorded.

None of these teeth were etched prior to application and polymerization of the bonding agent. Using the green color allowed for easy removal. Once the evaluation was completed, the bonding agent was removed and the patient dismissed.

Nonparametric Pearson's chi-square test was applied to the data for analysis. This test is designed for data analysis of smaller groups to determine, more predictably, if the differences seen occurred by chance alone or not.

Results

The analyzed data demonstrated a shift in the mandibles of the subjects away from the occlusal interferences. While some patients remained the same in their pre- and post-tests, the outcomes were not something that could have been expected by chance alone. In fact, the Pearson's chi-square test demonstrated a significant change in perceived occlusal contact ($p < 0.001$).

FIGURES 1 and **2** demonstrate the subjects' perception of their occlusion, both upon placement of the interference and then 15 minutes postplacement of the bonding resin. The graphs reveal the shift of occlusal perception away from the majority "right side" response from the beginning of the test to the end.

Discussion

The null hypothesis was rejected ($p < 0.001$).

Lack of mounted casts of the patients before and after bonding-agent application can be considered a limitation in this study and could have been used to measure discrepancies. The authors felt this was not needed because this was a feasibility study testing a concept and, from experience, the authors felt that patients are much more discerning of occlusal interferences even less than 8 μm. Likely, trying to determine differences in mounted casts would have been futile, primarily from the setting expansion of stone and the process of mounting casts. In addition to these variables, casts cannot offer biofeedback from the subject.

FIGURE 3. BMAGO shim challenge.

The literature has many papers demonstrating the ability of patients to detect, at minimum thresholds, the thicknesses of materials applied interocclusally. None of these papers asked what affects a subtle interference might have if left in place.[4–9]

Sletten[1] actually brings up the issue of what happens when a very small occlusal interference is added to an otherwise stable occlusal platform. While the test was anecdotal, this project was an attempt by the authors to demonstrate that very small prematurities can cause avoidance behaviors.

Conversely, the BMAGO protocol will identify posterior occlusal interferences, when 0.003-inch tin shims are placed in the anterior region. Even though the patient rightfully insists anterior prematurities exist prior to this "shim challenge," the interference is usually located in the posterior segments (**FIGURE 3**). Invariably, when patients come in and are complaining of a "high spot" in their bite (on the BMAGO), they are pointing to the "effect" and not the "cause." The protective neural guidance system (PNGS) had earlier been alerted and was in play attempting to find the best solution to the perceived prematurity. At this visit, the mandible will be in the best adaptive position away from the real problem: the posterior interference. Depending on the severity of the malocclusion, this may become "uncomfortable." Ironically, adjusting where the un-deprogrammed patient is pointing is a very common mistake. It only serves to exacerbate the occlusal problem the clinician wishes to correct. The BMAGO adjustment protocol demonstrates how subtle posterior interferences cause neuromuscular shifting away from interferences.

Asserting that an optimal model of occlusion exists, clinicians have observed premature wearing of canines early in a person's life right after complete dentitions have been achieved.[1,2,15] Even Tillis[14] warns of sealants adversely affecting occlusion.

Invariably, when patients come in and are complaining of a "high spot" in their bite (on the BMAGO), they are pointing to the "effect" and not the "cause."

The authors of this paper decided to attempt a more formal study, employing the methods mentioned in the anecdotal testing in the Sletten[1] paper. However, they did not use a stabilized BMAGO as the occlusal platform. When setting up this proof-of-concept study, the authors were less concerned about confounding factors because studying tolerances so minuscule had never been attempted before. Interestingly, many more compounding factors became apparent when performing the tests.

The obvious limitation of this study was to test the concept on generic patients where the larger concern of making sure everything applied during the testing was reversible.

A larger study could create a more homogeneous population that would include stable occlusions, while eliminating unstable TMJs, malocclusions, orthodontic patients, etc. Future studies might be performed on patients with newly restored and balanced occlusions. In this way, the dynamics of individual occlusions could be controlled and predictable. Pre- and posttreatment mounted casts could also be scanned and analyzed. This, possibly, could allow better certainty and prediction of avoidance behavior patterns as well as their direction.

The results from this study revealed a significant change in perception of occlusal contact, rejecting the null hypothesis. This warrants a more sophisticated and calibrated study.

Furthermore, sophisticated occlusal avoidance patterns using patients already stabilized on a BMAGO as reported in the article by Sletten[1] could be another topic for study.

Patient selection could have influenced results. For example, this author observed one subject's occlusal contacts as having a significant lingual incline contact on the mesiobuccal cusp of tooth No. 19 prior to applying the bonding agent. Even though the patient reported tooth No. 30 to be heavier with the initial application of the bonding agent to the mesiobuccal cusp, the heavy contact still remained on tooth No. 30 at the end of the test. One cannot know if the incline contact of tooth No. 19 was just heavier or if the incline contact was causing an avoidance behavior that was greater than the interference set up by the bonding agent. Analysis of patient occlusion in a more sophisticated trial would provide more insight. In addition to having the subject self-report, a clinical examination of occlusal contacts prior to testing would be crucial.

The investigators thinned the bonding agent with air well beyond the manufacturer's recommended protocol.

While the investigators were confident the thicknesses obtained in the study were much thinner than the minimal 50 µm thicknesses claimed by the manufacturer, there is no way to prove this to be the case. The limitation of this method was that precision with the bonding agent thickness was not possible. A future study would require more precision and calibration with selection and application of the bonding agent as well as interinvestigator calibration.

Although a calibration session for applying the bonding agent was conducted for the students performing the tests, results may have been skewed due to potential interoperator error among four testers. At issue would be the variance of thicknesses of the bonding agent, 50–90 µm, if standard manufacturer protocols were applied. Selecting another product with thinner cured thicknesses and less dependence on the thinning techniques would improve outcomes as well. A human hair is close to 70–100 µm in thickness. This provides some perspective as to the dimension used for this study. Interferences in micrometer dimensions iatrogenically introduced into a system can and do cause the patient to shift away from these interferences.

Even though adaptive systems have been shown to change occlusal contact positions via the bony and ligamental changes, this is not an immediate effect. Further, these animal studies were done by intentionally inflicting macropathologies on their subjects. The type of histological change recorded, necessarily, takes time. Lastly, animals are incapable of providing verbal feedback to the clinician. This element is critical to discovering what the patient really feels.

Animals and humans adapt to all kinds of detriments in order to survive.

The subtleties of this current study would be like comparing this immediate occlusal change to a person walking with a rock in their shoe. The brain will not usually allow the person to walk on the rock. If the rock is under the heel, the person will likely shift weight to their toes until the problem can be rectified. Apparently, a similar event happens with subtle occlusal interferences.

Another obvious question arises regarding an iatrogenic interference. Is a bony change going to happen when only one aspect of the tooth morphology is changed? Unlike previous studies where macroocclusal changes were made in the subjects, the current study was observing one simple change in occlusal contact, not a whole occlusal table or quadrant(s). More research is needed on this subject.

Awareness of the phenomenon of avoidance patterns, due to subtle occlusal interferences, may ultimately have significant impacts on the health of patients long term.

If the stomatognathic system is so sensitive as to avoid a prematurity much less than 50 µm thick, one can speculate what a premature, misplaced sealant can do to a developing dentition from both a skeletal and dental aspect. The ramification of a slightly hyperoccluding filling or crown on a patient's neuromuscular system also becomes a consideration as it relates to anterior tooth wear. Bioaesthetic dentists who base their treatment from an optimal model of occlusion have observed that the first teeth to wear are, in fact, the canines followed by the central incisors.[2]

The dental profession has benefited from the forgiving, highly adaptive nature of the stomatognathic system. This inference is attested to by the numerous pathologic inflictions done to monkeys decades ago. Even dental literature downplays the effects of occlusion in dysfunction and TMD.[16,17] The results from this study raise some questions: What happens to a patient who has, over the years, received dental work that had occlusal discrepancies ranging from 10–50 µm with restorations placed over the first adult half of their lives? Could worn, overloaded and broken teeth or TMD issues be sequellae of these minor interferences? At what point does this positive, adaptive and protective system get pushed beyond its ability to cope?

Awareness of the phenomenon of avoidance patterns, due to subtle occlusal interferences, may ultimately have significant impacts on the health of patients long term. Another purpose of this study was to demonstrate the acuity of the stomatognathic system. The dentist/patient relationship is critical in achieving a well-balanced, finely tuned occlusion. If patients can detect interferences less than the gold standard of 8 µm, shouldn't the treating dentist listen to what the patient is saying rather than rely on the shape, color and intensity of the occlusal spots being marked? Further, this author has observed that the best detection of an occlusal interference is on the initial closure. By the second and third tapping, the patient's system is already trying to avoid the interference. Multiple tapping is counterproductive.

Even Ho[13] cites histologic changes in the tooth-PDL-socket relationship to lateral occlusal forces.

This study encourages further exploration of optimally functioning dental systems. Investigating occlusal avoidance behaviors to minimal interferences could be one possible starting point.

Conclusions

Within the limitation of this study, the following conclusions can be drawn:

- Minimal increases in occlusal contacts result in a shift of the mandible along with a shift in the perception of occlusal contact position, away from the interference, within a short period of time.
- The clinical significance of multiple iatrogenic minor occlusal interferences could potentially cause significant pathology over time and should be studied.
- Further formalized study with a larger sample size could offer further insight. ■

ACKNOWLEDGMENTS

The authors thank Udo Oyoyo, PhD, from the Loma Linda University School of Dentistry for his statistical expertise and the Foundation for Bioesthetic Dentistry for use of the BMAGO shim challenge photo.

REFERENCES

1. Sletten WO, Taylor LP, Goodacre CJ, Dumont TD. The effect of specifically designed and managed occlusal devices on patient symptoms and pain: A cohort study. *Gen Dent* 2015 Mar–Apr;63(2):46–52.
2. Lee RL. Esthetics and its relationship to function. In: Rufenacht CR ed. *Fundamentals of Esthetics*. Chicago: Quintessence Publishing; 1990:137–209.
3. Rugh JD, Hedricson WD, Hatch JP, Glass BJ. The San Antonio CATs Initiative. *J Am Coll Dent* 2010 Summer;77(2):16–21.
4. Suganuma T, Ono Y, Shinya A, Furuya R. The effect of bruxism on periodontal sensation in the molar region: A pilot study. *J Prosthet Dent* 2007 Jul;98(1):30–5.
5. Uchida M. Sensory receptors on oral thickness sensation. *Kokubyo Gakkkai Zasshi* 1999 Mar;66(1);1–7 (Japanese), abstract only.
6. Calderon P, Kogawa E, Corpas L, Lauris J, Conti P. The influence of gender and bruxism on human minimum interdental threshold ability. *J Appl Oral Sci* 2009 May–Jun;17(3):224–8.
7. Siirila HS, Laine P. Occlusal tactile threshold in denture wearers. *Acta Odontol Scand* 1969 May;27(2):193–7.
8. Tryde G, Freydenberg O, Brill N. An assessment of the tactile sensibility in human bite force: An evolution of quantitative method. *Acta Odontol Scand* 1962 Aug;20:233–56.
9. Williams W, Lapointe L, Thornby J. Interdental thickness discrimination by normal subjects. *J Dent Res* 1974 Nov–Dec;53(6):1404–7.
10. Blankenship JR, Ramfjord SP. Lateral displacement of the mandible in Rhesus monkeys. *J Oral Rehabil* 1976 Jan;3(1):83–99.
11. Ramfjord SP, Blankenship JR. Increased occlusal vertical dimension in adult monkeys. *J Prosthet Dent* 1981 Jan;45(1):74–83.
12. Hannam AG, Stavness BE, Lloyd JE, Fels S, Miller AJ, Curtis DA. A comparison of simulated jaw dynamics in models of segmental mandibular resection versus resection with alloplastic reconstruction. *J Prosthet Dent* 2010 Sep;104(3):191–8. doi: 10.1016/S0022-3913(10)60120-5.
13. Ho SP, Kurylo MP, Grandfiled K, Hurng J, Herber RP Ryder MI, Altoe V, Aloni S, Fang J, Webb S, Marshall GW, Curtis DA, Andrews JC, Pianetta P. The plastic nature of the human bone-periodontal ligament-tooth. *Bone* 2013 Dec;57(2):455–67. doi: 10.1016/j.bone.2013.09.007.
14. Tillis TS, Stach DJ, Hatch RA, Cross-Poline GN. Occlusal discrepancies after sealant therapy. *J Prosthet Dent* 1992 Aug;68(2):223–8.
15. Taylor LP, Sletten WS, Dumont TD. The effect of specially designed and managed occlusal devices on patient symptoms of tinnitus: A cohort study. *Cranio* 2017 Nov 30:1–10. doi: 10.1080/08869634.2017.1404285. Epub 2017 Nov 30.
16. Turp J, Greene C, Strub J. Dental occlusion: A critical reflection on past, present and future concepts. *J Oral Rehabil* 2008 Jun;35(6):446–53. doi: 10.1111/j.0305-182X.2007.01820.x.
17. Rinchuse RJ, Kandasamy S. Myths of orthodontic gnathology. *Am J Orthod Dentfacial Orthop* 2009 Sep;136(3):322–30. doi: 10.1016/j.ajodo.2008.04.021.

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