THE JOURNAL OF PROSTHETIC DENTISTRY

SYSTEMATIC REVIEW

Impact of lateral occlusion schemes: A systematic review

Jaafar Abduo, BDS, DClinDent, MRACDS (Pros)[a] and Marc Tennant, BDSc, PhD, AFCHSE[b]

When restoring dentition, the clinician encounters a clinical dilemma of which occlusion scheme to use. Many occlusion rehabilitation philosophies have been proposed in the literature, and in general, the available lateral occlusion schemes are canine-guided occlusion (CGO), group function occlusion (GFO), and bilateral balanced occlusion (BBO).[1] Although at maximal intercuspation they might have similar occlusal contacts, these schemes differ in the amount of contact during lateral movement. CGO is distinguished by prominent vertical and horizontal overlap of canine teeth that prevents posterior tooth contact in the lateral movement of the mandible.[2] Dentition with GFO exhibits multiple contacts between maxillary and mandibular teeth in lateral movement on the working side.[2] In addition to the occlusal contacts of GFO, BBO has additional posterior tooth contact on the nonworking side.[2] Although each lateral occlusion philosophy has its advocates,[1,3] clinical evidence supporting the superiority of any one philosophy is limited.[4,5]

Instead of rigidly following a preconceived lateral occlusion philosophy, it is worthy to ask the question of what the influence of the lateral occlusion scheme is on patient's comfort, masticatory system physiology and prosthesis longevity. Therefore, the purpose of this systematic review was to investigate the clinical implications of lateral occlusion schemes on the restored dentition. The null hypotheses were (1) there is no effect of lateral occlusion scheme on patient comfort and masticatory physiology, and (2) there is no effect of lateral occlusion scheme on restoration longevity.

ABSTRACT

Statement of problem. Although several lateral occlusion philosophies have been proposed in the literature, there is a lack of compelling evidence supporting any scheme.

Purpose. The purpose of this systematic review was to investigate the clinical implications of different lateral occlusion schemes.

Material and methods. A literature search was completed through PubMed (MEDLINE), Google Scholar, and Cochrane Library, up to January 2014. The literature search aimed to retrieve 2 study categories: group 1: comparative studies; group 2: clinical outcome studies. The inclusion criteria were peer-reviewed human clinical studies published in English. The search was further supplemented by manual searching through the reference lists of the selected studies.

Results. The initial search revealed a total of 680 studies; however, after applying the inclusion criteria, 26 studies were found suitable for the analysis (13 for group 1 and 13 for group 2). The most commonly evaluated lateral occlusion schemes were canine-guided occlusion (CGO) and group function occlusion (GFO). Group 1 studies evaluated the impact of lateral occlusion schemes on muscular electromyographic (EMG) activity, condylar displacement, mastication, and mandibular movement. Group 2 studies evaluated the impact of restored occlusion on longevity, patient comfort, and pathologic consequences. CGO was associated with narrower mastication and less EMG activity of the masticatory muscles during clenching. GFO was associated with wider mandibular movement and quicker mastication. During mastication, there was no difference in EMG activity between the 2 lateral occlusion schemes. Furthermore, the long-term studies indicated that there is no difference between the 2 schemes in patient comfort and restoration longevity.

Conclusion. Although there are immediate differences between the different lateral occlusion schemes, patients have the capability to successfully adapt to CGO or GFO. (J Prosthet Dent 2015;114:193-204)

MATERIAL AND METHODS

Search strategy and selection criteria

An electronic literature search was accomplished in January 2014 through PubMed (MEDLINE), Google

[a]Senior Lecturer, Melbourne Dental School, School of Anatomy, Physiology and Human Biology, University of Western Australia, Crawley, Western Australia, Australia.
[b]Professor, School of Anatomy, Physiology and Human Biology, School of Anatomy, Physiology and Human Biology, University of Western Australia, Crawley, Western Australia, Australia.

Clinical Implications

Occlusion scheme might influence masticatory muscle activity, condylar displacement, mastication, and mandibular movement; however, because long-term studies reflect patient acceptance of occlusion alteration, the clinical significance of these differences is yet to be determined.

Scholar, and Cochrane Central Registrar of Controlled Trials. Through the PubMed database, the Boolean operator was used to combine the following key words: (lateral occlusion OR dynamic occlusion OR excursive occlusion) AND (canine guided OR canine protected OR group function OR balanced) AND (dental) OR (implant). All the articles related to dental occlusion were retrieved from the Cochrane Database. The Google Scholar search engine was used to retrieve additional articles by combining the following key words: dental occlusion, lateral, dynamic, excursive, guidance, canine, group function, balanced, implant, restoration, fixed, and prosthesis. No publication year limit was applied. The purpose of the search was to obtain all the clinical studies that evaluated the impact of lateral occlusion schemes, including impact on physiologic response, longevity, and patient acceptance.

Study selection was performed in 3 stages: (1) study selection according to relevance of the title, (2) study selection according to abstract relevance, and (3) full text analysis and cross-matching against predefined inclusion criteria (Table 1). In addition, the literature search was endorsed with manual searching of the bibliographies of all the included studies.

Studies classification

Two study categories were considered for this review: group 1, comparative studies, in which the study compares multiple lateral occlusion schemes, and group 2, clinical outcome studies, in which the study describes the applied occlusion scheme for the restored dentition.

The definition of each lateral occlusion scheme was adopted from the Glossary of Prosthodontic Terms[2]:

CGO. The vertical and horizontal overlap of the canine teeth disengages the posterior teeth in excursive movements of the mandible.

GFO. Multiple contact relations between the maxillary and mandibular teeth in lateral movements on the working side. Because there is no specification regarding the amounts of the present contact, 2 or more simultaneous contacts on the working side were considered as GFO.

BBO. Bilateral, simultaneous, anterior, and posterior occlusal contact of teeth in centric and eccentric positions. Because BBO as defined here rarely exists naturally, balancing contacts that do not interfere with smooth mandibular movements were considered as indicators of BBO.

Table 1. Inclusion criteria

- Peer-reviewed journal article
- Human clinical study
- Adult participants
- Asymptomatic participants
- Occlusion alterations were executed by fixed restoration/prosthesis
- Cross-sectional retrospective or prospective study
- English language publication

RESULTS

Literature search

The electronic search yielded a total of 680 articles. After analysis of title relevance, 621 articles were excluded. Screening of abstracts excluded an additional 24 articles. Thus, 35 articles were suitable for full-text analysis. Cross-matching against the inclusion criteria yielded a total of 16 articles suitable for inclusion. Manual searching through the references of the selected articles revealed 10 additional articles suitable for inclusion. Thus, a total of 26 articles were included in this review. Only relevant information about lateral occlusion schemes was extracted; nonphysiologic occlusions were excluded from the analysis.

Description of studies

Of the 26 studies, 13 were comparative studies (group 1) and 13 were long-term studies (group 2).

Group 1 studies evaluated the immediate response to alteration of the lateral occlusion scheme by the following methods:

Electromyography (EMG) (Table 2). The electrical activities of masticatory muscles were recorded and used to evaluate the effect of the lateral occlusion scheme on muscle response to different mandibular movements.

Mandibular movement (Table 3). The impact of lateral occlusion on mandibular movement or condylar position was evaluated when the teeth are masticating.

The participants were requested to undertake the following movements:

Physiologic: mastication, sliding from intercuspal position to edge-to-edge position (eccentric grinding), and sliding from edge-to-edge position to intercuspal position (concentric grinding).

Nonphysiologic: maximal clenching in the intercuspal position, maximal clenching in the edge-to-edge position, and submaximal edge-to-edge clenching. The aim of these movements was to simulate the muscle reaction to parafunctional activities.

The studies either selected participants with existing occlusion or experimentally altered the occlusion by bonding occlusal overlay or altering the prosthesis. The

Table 2. Implications of lateral occlusion scheme on muscle EMG activity

Study (year)	Study Design	Participant (description) Existing Occlusion Scheme	Evaluated Movements	Evaluated Muscles	Occlusion Alteration Method	Lateral Occlusion Scheme	Duration of Alteration	Relevant Information
Belser and Hannam (1985)[6]	Cross-sectional	12 (intact dentition, no masticatory dysfunction) Natural GFO	Mastication Maximal vertical clenching and eccentric grinding	Anterior temporalis Posterior temporalis Masseter	Bonded metal overlays No OVD increase	CGO GFO	NA	CGO significantly reduced EMG activity during clenching, but not during mastication
Akoren and Karaagaclioglu (1995)[11]	Cross-sectional	30 (intact dentition, no masticatory dysfunction, no previous treatment) 15 CGO 15 GFO	Mastication Eccentric grinding	Anterior temporalis Masseter	No alteration	CGO GFO	NA	No significant difference between occlusion schemes during mastication During eccentric clenching, GFO increased EMG activity of anterior temporalis, but there was no effect on masseter
Okano et al (2002)[9]	Cross-sectional	20 (intact dentition, no masticatory dysfunction) Natural CGO	Maximal edge-to-edge clenching	Anterior temporalis Posterior temporalis Masseter	Bonded metal overlays No OVD increase	CGO GFO sGFO BBO	NA	Statistically significant effect of lateral occlusion scheme on EMG activity, on working and nonworking side CGO caused lowest EMG activity Increasing posterior teeth contacts resulted in increased total EMG activity Balancing contacts caused greater EMG activity than other occlusion schemes
Valenzuela et al (2006)[12]	Cross-sectional	40 (intact dentition, no masticatory dysfunction, no previous treatment) 20 CGO 20 GFO	Eccentric grinding Edge to edge clenching Concentric grinding	Suprahyoid Infrahyoid	No alteration	CGO GFO	NA	GFO is associated with insignificantly more EMG activity Location of jaw and function is more influential on EMG activity than occlusion scheme More EMG activity for clenching than grinding
Miralles et al (2007)[13]	Cross-sectional	40 (intact dentition, no masticatory dysfunction, no previous treatment) 20 CGO 20 GFO	Edge to edge clenching Concentric grinding Eccentric grinding	Supra-hyoid Infra-hyoid	No alteration	CGO GFO	NA	GFO is associated with insignificantly more EMG activity Location of jaw and function is more influential on EMG activity than occlusion scheme More EMG activity for clenching than grinding
Okano et al (2007)[14]	Cross-sectional	20 (intact dentition, no masticatory dysfunction) Natural CGO	Maximal edge-to-edge clenching	Anterior temporalis Posterior temporalis Masseter	Bonded metal overlays No OVD increase	CGO GFO sGFO BBO	NA	There is significant difference between different occlusion schemes Masseter activities remained same Significant increase for anterior temporalis EMG for GFO and BBO Increasing posterior teeth contacts resulted in increased total EMG activity
Campillo et al (2008)[15]	Cross-sectional	30 (intact dentition, no masticatory dysfunction, no previous treatment) 15 CGO 15 GFO	Maximal intercuspal clenching Eccentric grinding Maximal edge-to-edge clenching Concentric grinding	Masseter	No alteration	CGO GFO	NA	No significant difference between occlusion schemes Location of jaw and function is more influential on EMG activity than occlusion scheme More EMG activity for clenching than grinding
Gutierrez et al (2010)[16]	Cross-sectional	30 (intact dentition, no masticatory dysfunction, no previous treatment) 15 CGO 15 GFO	Eccentric grinding Maximal edge-to-edge clenching Concentric grinding	Anterior temporalis	No alteration	CGO GFO	NA	CGO was associated with significantly less EMG activity than GFO
Rodriguez et al (2011)[17]	Cross-sectional	28 (intact dentition, no masticatory dysfunction, no previous treatment) 14 CGO 14 GFO	Eccentric grinding Maximal edge-to-edge clenching Concentric grinding	Sternocleidomastoid	No alteration	CGO GFO	NA	Significantly lower activity was observed with CGO than GFO
Valenzuela et al (2012)[18]	Cross-sectional	30 (intact dentition, no masticatory dysfunction, no previous treatment) 15 CGO 15 GFO	Eccentric grinding Maximal edge-to-edge clenching Concentric grinding	Supra-hyoid Infra-hyoid	No alteration	CGO GFO	NA	No significant difference between occlusion schemes

CGO, canine-guided occlusion; GFO. Group function occlusion; sGFO, semi-group function occlusion; BBO, bilaterally balanced occlusion; OVD, occlusal vertical dimension; EMG, electromyography; NA, not applicable.

Table 3. Implications of lateral occlusion scheme on mandibular movement

Study (year)	Study Design	Participant (description) Existing Occlusion Scheme	Method of Evaluation	Occlusion Alteration Method	Lateral Occlusion Scheme	Duration of Alteration	Relevant Information
Belser and Hannam (1985)[6]	Cross-sectional	30 (intact dentition, no masticatory dysfunction, no previous treatment) Natural GFO	Jaw movement during mastication	Bonded metal overlays No OVD increase	CGO GFO	NA	CGO is associated with narrower mastication movement
Jemt et al (1985)[7]	Cross-over	5 (fixed maxillary implant prosthesis opposed by natural dentition)	Jaw movement during mastication	Occlusion alteration of maxillary implant prosthesis	CGO GFO	4 mo 5 mo	Slightly steeper movement path was noted for CGO than GFO GFO was associated with more mastication cycle variation, lateral mandibular displacement, and mandibular velocity All participants found GFO to be more comfortable
Okano et al (2002)[9]	Cross-sectional	20 (intact dentition, no masticatory dysfunction) Natural CGO	3D condylar displacement during maximal edge-to-edge clenching	Bonded metal overlays No OVD increase	CGO GFO sGFO BBO	NA	On working side, condylar displacement was similar for all occlusion schemes Clenching with GFO caused significantly greater superior displacement of nonworking side condyle Clenching with BBO caused significantly less superior displacement on nonworking side On nonworking side, there was similarity between CGO and sGFO
Okano et al (2005)[10]	Cross-sectional	20 (intact dentition, no masticatory dysfunction) Natural CGO	3D condylar displacement during submaximal edge-to-edge clenching	Bonded metal overlays No OVD increase	CGO GFO sGFO BBO	NA	On working side, condylar displacement with CGO was greater than for GFO or BBO. This difference was insignificant with sGFO For nonworking side, BBO was associated with least condylar displacement followed by GFO. Statistical difference was between BBO and CGO
Salsench et al (2005)[8]	Cross-sectional	53 (intact dentition, no masticatory dysfunction, no previous treatment) 36 CGO or anterior protected occlusion 17 GFO	Duration of masticatory cycle during mastication	No alteration	CGO GFO	NA	CGO had highest lateral guidance angle and greatest mastication cycle duration GFO had less total duration of mastication Masticatory height for CGO and GFO was similar

CGO, canine-guided occlusion; GFO. Group function occlusion; sGFO, semi-group function occlusion; BBO, bilaterally balanced occlusion; OVD, occlusal vertical dimension; NA, not applicable.

evaluated occlusion schemes were CGO, GFO, and BBO. Some studies considered semigroup function occlusion (sGFO) in which the canines and the first premolars controlled the lateral movements.

Group 2 studies are long-term studies that reported the applied occlusion scheme in the prosthesis/restoration design. Although not specifically evaluating the impact of the lateral occlusion scheme, the studies investigated patient response, restoration longevity, and complications in situations resembling routine clinical practice. The lateral occlusion scheme was achieved by composite resin restorations (Table 4) and fixed dental and implant prostheses (Table 5). In several studies, the lateral occlusion scheme was altered in conjunction with increasing the occlusal vertical dimension (OVD). The implemented occlusion schemes were CGO, GFO, and BBO.

Outcome

Five comparative studies (Group 1) evaluated the effect of altering the lateral occlusion scheme on mastication and mandibular movement.[6-10] One was for unaltered natural occlusions,[8] 3 were for altered occlusion,[6,9,10] and 1 was for restored dentition with fixed implant prosthesis.[7]

Belser and Hannam[6] found that altering GFO to CGO narrowed the envelop of mandibular movements, while the muscle coordination during mastication was not altered. Likewise, Jemt et al[7] found CGO was associated with a slightly steeper movement path than GFO during mastication. Furthermore, their participants reported GFO to be more comfortable than CGO. Salsench et al[8] demonstrated that participants with CGO had the steepest lateral guidance angle, while participants with GFO had less vertical overlap.

In terms of mastication speed, Jemt et al[7] found GFO to be associated with greater mandibular velocity than CGO. Salsench et al[8] found that the duration of mastication is influenced by the occlusion scheme, and a longer mastication cycle was attributed to CGO than GFO. Because mastication height of GFO and CGO was similar, velocity of mastication speed was greater in GFO than CGO.[8]

In relation to the condylar displacement, maximal edge-to-edge clenching caused the condyles to displace regardless of the lateral occlusion scheme.[9] However, the lateral occlusion scheme altered the magnitude and direction of the condyle displacement. On the working side, there is an insignificant total displacement between the different occlusion schemes, while on the nonworking side, GFO caused the greatest displacement, followed by sGFO, CGO, and BBO, in that order. There was an insignificant difference between CGO and BBO

Table 4. Summary of studies that established lateral occlusion scheme by composite resin restorations

Study (year)	Study Design	Participant (description)	Method of Evaluation	Occlusion Alteration Method	Lateral Occlusion Scheme	Duration of Alteration	Relevant Information
Hemmings et al (2000)[28]	Prospective	16 (dentition with tooth wear)	Evaluated restoration longevity Subjective patient evaluation	Composite buildup OVD increase	CGO	30 mo	Success rate of composite restoration was 89.4% Restorative material has impact on survival of restoration Good patient satisfaction
Redman et al (2003)[29]	Prospective	31 (dentition with tooth wear)	Evaluated restoration longevity Subjective patient evaluation	Composite buildup OVD increase	CGO	Up to 6 y	No restoration failure in 1st year Half of failures occurred in 5th year Failure is related to bruxism and material properties Bulk fracture was not common 80% had evidence of wear
Poyser et al (2007)[27]	Prospective	14 (dentition with tooth wear)	Evaluated restoration longevity Subjective patient evaluation	Composite buildup OVD increase	CGO	2.5 y	6% complete loss of restoration High level of patient satisfaction Material loss was due to wear
Schmidlin et al (2009)[30]	Prospective	7 (dentition with tooth wear)	Evaluated restoration longevity Subjective patient evaluation	Composite buildup OVD increase	GFO	3 y	Most of restorations maintained anatomic form (97%) All patients demonstrated good to excellent acceptance of treatment
Attin et al (2012)[31]	Prospective	7 (dentition with tooth wear)	Evaluated restoration longevity Subjective patient evaluation	Composite buildup OVD increase	GFO	5.5 y	86% of restorations had good anatomic form All restorations were adequate No signs of masticatory dysfunction After 3 years, no deterioration of surface texture After 5 years, 28% of restorations had some surface deterioration
Al-Khayatt et al (2013)[26]	Prospective	15 (dentition with tooth wear)	Evaluated restoration longevity Subjective patient evaluation	Composite build-up OVD increase	CGO	7 y	Approximate survival rate of restoration was 85% Patients were satisfied with treatment

CGO, canine-guided occlusion; GFO. Group function occlusion; OVD, occlusal vertical dimension.

or GFO. The most prominent displacement was vertical on the nonworking side. Interestingly, another study by the same investigators applied submaximal edge-to-edge clenching and found different results.[10] CGO caused the greatest condylar displacement, followed by sGFO, GFO, and BBO. On the working side, there was a significant difference between CGO and GFO or BBO. On the nonworking side, the significant difference was between CGO and BBO. The researchers attributed the difference between the 2 studies to the difference in the magnitude of clenching force.

A total of 10 studies evaluated the effect of altering the lateral occlusion scheme on muscle activities by muscle EMG activity measurements.[6,9,11-18] Seven studies evaluated the effect of natural lateral occlusal scheme on EMG activity,[11-13,15-18] while the other studies experimentally altered the occlusion.[6,9,14] The evaluated muscles were the masseter, anterior temporalis, posterior temporalis, suprahyoid, infrahyoid, and sternocleidomastoid.

On unaltered dentition, Akoren and Karaagaclioglu[11] found no difference in the masseter and anterior temporalis muscle EMG activities between participants with CGO and GFO during mastication. However, during eccentric clenching, the anterior temporalis muscle had greater EMG activity with group occlusion, while the masseter EMG activity was not influenced. Campillo et al[15] confirmed that the masseter muscle was minimally affected during maximal intercuspal clenching, eccentric grinding, maximal edge-to-edge clenching, and concentric grinding. Rather, the mandibular position was the most influencing where clenching in the intercuspal position induced the greatest EMG activity. Gutierrez et al[16] found GFO caused a significantly higher EMG activity for the anterior temporalis muscle than CGO during eccentric and concentric grinding and edge-to-edge clenching. For the suprahyoid and infrahyoid muscles, Valenzuela et al[12,18] found GFO caused insignificantly greater activity than CGO during eccentric and concentric grinding and edge-to-edge clenching.[12,18] A similar outcome was confirmed for the sleeping position by Miralles et al.[13] For the sternocleidomastoid muscle, Rodriguez et al[17] found significantly lower activity for CGO than GFO during eccentric grinding, concentric grinding, and edge-to-edge clenching. The aforementioned studies found significant effects of the type of activity, where clenching generally caused more EMG activity than grinding. These studies suggested that jaw stability is more critical to the reduction of muscle EMG activity than the lateral occlusion scheme.

The studies that deliberately altered the occlusion scheme found similar outcomes as the studies on unaltered dentition. Belser and Hannam[6] confirmed that CGO caused a significant reduction of temporalis and masseter muscle EMG activity (by 50%) during clenching, while mastication did not alter the EMG activity. Okano et al[9] also found less combined temporalis and masseter muscle EMG activity for CGO followed by sGFO, GFO, and BBO during maximal clenching in

Table 5. Summary of studies that established lateral occlusion scheme by fixed dental and implant prostheses

Study (year)	Study Design	Participant (description)	Method of Evaluation	Occlusion Alteration Method	Lateral Occlusion Scheme	Prosthesis Support	Duration of Alteration	Relevant Information
Dahl and Krogstad (1985)[19]	Prospective	20 (dentition with tooth wear)	Clinical evaluation Subjective patient evaluation	Anterior teeth crowns according to Dahl concept OVD increase	CGO	Teeth	Up to 5.5 y	None of restored teeth had endodontic complications No crown had to be replaced due to excessive wear No development of masticatory dysfunction symptoms
Gross and Ormianer (1994)[20]	Prospective	8 (dentition with tooth wear and no signs of masticatory dysfunction)	Subjective patient evaluation Masticatory system evaluation	Provisional prostheses OVD increase	CGO	Teeth	1 mo	All participants adapted to new occlusion scheme
Yi et al (1996)[21]	Retrospective	34 (patients history of periodontal disease)	Evaluation of incidence of each occlusion scheme Subjective patient evaluation	Cross-arch prostheses Flattened occlusal morphologies	CGO: 16% GFO: 51% GFO and CGO: 14% BBO: 19%	Teeth and implants	More than 10 y	None of examined occlusal variables were related to long-term results Great majority of patients were satisfied with function of their prostheses Subjective function was not significantly influenced by occlusal variables
Ormianer and Gross (1998)[22]	Prospective	8 (dentition with tooth wear and no signs of masticatory dysfunction)	Masticatory system evaluation	Definitive prostheses OVD increase	CGO	Teeth	2 y	All participants adapted to new occlusion scheme
Kinsel and Lin (2009)[23]	Retrospective	152 (single and multiple-unit implant prostheses)	Evaluated incidence of ceramic chipping	Single implant crown or fixed dental prosthesis	CGO: 82% GFO: 18%	Implants	Variable	Ceramic chipping were significantly associated with opposing implant prostheses, bruxism and not wearing occlusal device For CGO, 15.9% of patients experience ceramic fracture and 5.3% of implants had ceramic fracture For GFO, 51.9% of patients experienced ceramic fracture and 16.1% of implants had ceramic fracture At patient level, significantly more complications with GFO that CGO. At implant level, there was no significant difference between 2 schemes
Ormianer and Palty (2009)[24]	Retrospective	30 (natural dentition and whole arch implant prosthesis) 10 (natural dentition in both arches) 10 (natural dentition in one arch against implant prosthesis in opposing arch) 10 (implant prostheses in both arches)	Subjective patient evaluation Radiographic assessment of alveolar bone around teeth and implants Evaluated restoration longevity	Definitive prostheses OVD increase	GFO	Teeth Implants	2-3 mo	All participants adapted to new occlusion scheme More bone loss and tooth failure with prosthesis supported by natural dentition in 2 arches More mechanical complications such as veneer fracture was for patients with implant prosthesis in 2 arches
Sierpinska et al (2013)[25]	Prospective	50 (dentition with tooth wear)	EMG (anterior temporalis, superficial masseter, anterior digastric, sternocleidomastoid) Digital occlusion examination	Definitive prostheses OVD increase	GFO	Teeth	3 mo	Mean value of functional EMG activity during clenching immediately posttreatment decreased compared to pretreatment After 3 months, no side effects in form of masticatory dysfunction, mastication, and comfort After 3 months period of adaptation, posttreatment EMG activity had increased to levels similar to pretreatment levels

CGO, canine-guided occlusion; GFO. Group function occlusion; BBO, bilaterally balanced occlusion; OVD, occlusal vertical dimension.

edge-to-edge position. CGO produced significantly less activity than all other occlusion schemes. In addition, with sGFO, the EMG activity was significantly less than in BBO. In another study, Okano et al confirmed their previous observation.[14] However, no statistical difference was observed for the masseter muscle EMG activity for any scheme. For anterior and posterior temporalis muscles, no significant difference on the working side was observed. On the nonworking side, the CGO caused significantly less EMG activity than GFO and BBO for the anterior temporalis muscle. For the posterior temporalis muscle, CGO caused significantly less EMG activity than BBO.

From the included studies, it appears that CGO is associated with a narrowing mastication cycle laterally and steeper mandibular motion. GFO appears to increase the velocity of mastication. There are indications that the presence of more tooth contacts can reduce the loads on the condyle on the working and nonworking sides during clenching. There is a tendency for CGO to cause less EMG activity than other occlusion schemes. In addition, the EMG activity tends to increase with increasing number of posterior tooth contacts and cross-arch contacts. However, during physiologic movements, such as mastication and grinding, this difference appears to be minimal. The most commonly influenced muscle is the anterior temporalis muscle.

Seven studies evaluated the long-term outcome of the modified occlusion scheme by fixed prostheses (Group 2).[19-25] Four of them were solely for fixed prostheses supported by teeth.[19-22,25] One study was for implant prostheses[23] and 1 study included tooth- and implant-supported prostheses.[22] Six studies evaluated the long-term outcome of the modified occlusion scheme by composite resin restorations.[26-31] Only 2 studies attempted to find the implications of the existing lateral occlusion scheme.[21,23]

Three studies provided CGO[19,20,22] by fixed prosthesis and 4 studies by composite restorations.[26-29] None of the studies reported biologic or mechanical complications associated with the provided occlusion schemes. Furthermore, patient acceptance of the new occlusion scheme was reported.[20,22] The composite restorations suffered from some mechanical degradation in the form of wear, chipping, and margin deterioration over a period of 3 to 6 years. However, the failure cannot be attributed to the applied lateral occlusion scheme. Instead, material properties and bruxism appear to be more influential on the success of composite resin restorations.[28,29]

For GFO, 2 studies restored the occlusion by fixed prosthesis[24,25] and 2 studies altered the occlusion by composite resin.[30,31] Similar to CGO, all the studies reported patient acceptance of the new occlusion, and biologic or mechanical complications were not attributed to the occlusion scheme. The composite restoration studies reported surface deterioration and mechanical complications that were not related to the occlusion scheme.[30,31] Sierpinska et al reported that following prostheses insertion, the muscle EMG activity during maximal clenching within the temporalis, masseter, and digastric muscles had decreased, while the EMG activity for sternocleidomastoid muscle had increased. After 3 months of function, the EMG activity was restored to pretreatment levels.[25]

One study evaluated the incidence of lateral occlusion schemes for periodontally treated restored dentition with cross-arch fixed dental prosthesis.[21] The researchers found that 51% of their patients had GFO, 16% had CGO, and 14% had mixed occlusion. The prevalence of BBO was 19%. They noted that most of the patients were satisfied with their function in terms of mastication, esthetics, phonetics, and comfort. Patients with limited supporting tissues (less than 70%) had more difficulties masticating hard foods. No relationship was observed between the occlusion scheme and dysfunction or subjective function.

Interestingly, the researchers reported that CGO tended to be the dominant scheme if the dentition is ideal. When there was no mobility and more than 50% of the supporting periodontium remained, GFO tended to be more frequent. BBO was found to be associated with very mobile teeth. Because the prostheses were stable, the researchers postulated that the occlusal variable cannot contribute to the long-term result. Another study evaluated the lateral occlusion as a factor for implant-supported prosthesis complications.[23] The most commonly applied occlusion scheme was CGO (82.2%). Patients with GFO were found to have about 3 times more mechanical complications than those with CGO. However, the most prominent risk factors for mechanical complications were the presence of bruxism and an implant prosthesis opposing another implant prosthesis. Similarly, Ormianer and Palty reported that more mechanical complications occurred for implant prosthesis opposing another implant prosthesis when compared with implant prosthesis opposing restored natural dentition, or when all prostheses are supported by natural teeth.[24]

From the previous studies, it appears that patients have the capacity to adapt to CGO or GFO as a new lateral occlusion scheme. The selected lateral occlusion scheme appears to have minimal impact on patient comfort and biologic or mechanical complications. Instead, mechanical complications are associated with other risk factors such as bruxism, restorative material properties, and implant prosthesis occluding against implant prosthesis.

DISCUSSION

This systematic review determined that the lateral occlusion scheme has an impact on muscle activity, mastication, and mandibular movements. CGO appears to exhibit some protective role, while GFO results in quicker mastication. Therefore, the hypothesis that there is no effect of lateral occlusion scheme on the patient's comfort and masticatory physiology is rejected. However, long-term studies have revealed an equivocal outcome in relation to the long-term effects of lateral occlusion. Thus, the hypothesis that there is no effect of the lateral occlusion scheme on restoration longevity is accepted. Consequently, the observed difference between the lateral occlusion schemes could be of significance at an experimental level, while clinically, the significance of the difference is questionable.

Physiologic implications of lateral occlusion scheme

Uncontrolled dynamic occlusion was classically believed to precipitate pathologic consequences. As the mandible slides along cuspal inclines, the forces are distributed to the teeth, supporting structure, muscles of mastication, and the temporomandibular joint (TMJ).[32,33] Therefore, uncontrolled forces due to the occlusion scheme or parafunctional activities might affect the physiologic balance.[34] From the included studies, there are indications that CGO exhibits some protective roles for posterior teeth, masticatory muscles, and the TMJ complex. However, it was observed that GFO is more efficient for chewing and is more comfortable.

The narrowness of the chewing cycle of CGO could be attributed to the presence of increased vertical overlap between the anterior teeth.[7,8] This feature could translate clinically to less magnitude of lateral mandibular movement and, as a result, less posterior tooth contact laterally.[35] Eventually, with CGO, the posterior teeth are subjected to less oblique forces and tensile stresses, which are more traumatic to tooth structure.[36,37] Instead, the posterior teeth receive vertical forces primarily.[11] This could potentially support the protective role of canines in mutually protected occlusion.

However, although the muscle coordination is similar to CGO,[6] GFO was distinguished by the wider range of lateral movement in the occlusal phase of chewing. This was attributed to the reduced vertical overlap observed for GFO as a result of canine wear.[8] It could be speculated that the posterior teeth will be subjected to more stresses laterally. However, some authors have proposed that as tooth wear proceeds, the surface contact area between teeth increases as well, which might dissipate the occlusal forces, rendering them less susceptible to future wear compared with sharp cusps.[38,39]

The included studies evaluated the risk of temporomandibular joint disorder (TMD) development by condylar displacement and muscle EMG activity. The condylar displacement has been investigated to estimate TMJ loading wherein a larger upward displacement of the condyle could be associated with a larger compressive load within the TMJ.[9] The outcome of this review indicates that clenching contributes to upward condylar movements, which coincides with findings in other investigations.[40,41] In addition, the occlusion scheme influences the magnitude of condylar displacement[9,10] when the mandible is in edge-to-edge position. Regardless of the clenching level, BBO caused the least vertical condylar displacement. Such an observation could be related to the upward mandibular movement being resisted by the bilateral posterior tooth contacts.[42,43] It has been postulated that balancing contacts might protect against compressive TMJ loading, causing fewer incidences of joint noises.[9,44] However, during maximal clenching, CGO caused less nonworking condylar displacement than GFO and was similar to BBO.[9] This could be due to the inability to clench with the heavy occlusal force in the edge-to-edge position with CGO in comparison to GFO. Because the canine is the primary tooth in contact laterally, the occlusal loads are concentrated on the canines, leading to the excessive stimulation of the mechanoreceptors,[35,45] which reduce muscle contraction.[46] On the contrary, because of the additional contacts laterally, GFO participants were able to induce more occlusal loads during maximal clenching. Such an observation is confirmed by all the included EMG studies, which indicated participants were able to produce greater EMG activity during edge-to-edge clenching.[9,14,16] However, for submaximal clenching, CGO caused a more superior condylar displacement than GFO.[10] The difference between the magnitudes of clenching could be related to mandibular deformation after maximal clenching on the nonworking side and subsequent condylar elevation.[47] Because participants were able to exert more maximal clenching with GFO, mandibular deformation might occur, leading to more upward nonworking condylar displacement. Despite the statistically significant difference between the 2 schemes, the clinical impact is yet to be determined. Because the maximal displacement is about 0.6 to 0.8 mm, attributing adverse TMJ consequences to such displacement is questionable.[9,10]

EMG activity is a commonly used as an indicator of muscle activity in research;[48,49] where large EMG activity induced by clenching or parafunctional activities can be indicative of muscle fatigue.[50,51] Selective occlusion alteration is thought to alleviate signs and symptoms of TMJ,[6] which is based on the assumption that certain occlusal interferences may act as triggers in the development of bruxism or cause pain in the masticatory muscles by disturbing their pattern of activity; however, the physiologic processes that ensue are poorly understood.[52] Still, providing an occlusion scheme that can reduce the EMG activity of muscles of mastication during function or parafunction is desirable. This systematic review indicates that it is very likely that altering the lateral occlusion scheme influences the EMG activity during parafunctional activities, while normal physiologic function (mastication) was found to minimally influence the muscles activity. In addition, masticatory muscles were influenced by the lateral occlusion scheme differently, with the anterior temporalis muscle being the most affected. In support of the protective role of CGO, several studies found that CGO is associated with less EMG activity during parafunctional activities,[9,14,16] while BBO was clearly associated with the greatest EMG activity.[9,14] Overall, as the number of contacts increased on the working side, the magnitude of EMG activity also increased.[9,14] This could be due to the inability of patients to exert excessive clenching forces where there are fewer teeth contacts. Interestingly, the significant effect of different occlusion schemes on muscle activities was not always observed from all the studies. Some muscles (anterior temporalis and sternocleidomastoid)[16,17] appear to be more affected than others (masseter, infrahyoid, and suprahyoid).[12,13,15,18] Furthermore, the dynamic position appears to play a significant role for muscles activities. For example, parafunctional activities, primarily edge-to-edge, were responsible for the greatest increase in EMG activities. Clinically, muscle activities will be more complex as there is no standardized position for parafunctional activities. Furthermore, a genuine specific lateral occlusion scheme is not commonly occurring. For example, many people have GFO for the first 1- to 2-mm excursion followed by established CGO in the edge-to-edge position.[53] In addition, balancing contacts were found to be very common within the normal population,[53] which could lead to a deviation from the outcome of the experiments included that are based on ideal scenarios or experimental setup.

In terms of function, there are some signs that GFO facilitates quicker mastication. This could be attributed to the greater tooth contacts during lateral movements and greater freedom in lateral movement. Similar observations were made from the chewing experiment by Buschang et al, who found participants with an increased vertical overlap had slower mastication and a narrowing mastication pattern.[54]

For natural dentition, there is no evidence that lateral occlusion scheme influences patient satisfaction.[21] However, for implant-supported prostheses, GFO might be more comfortable for patients with fixed maxillary implant-supported prosthesis over a period of a few months.[7] This could be related to the lack of proprioception for the implant-supported prosthesis and the greater freedom for mandibular movement. Such findings could support the recommendation of a greater freedom of movement.

Long-term effect of lateral occlusion scheme

From the long-term studies, this systematic review supports that there is no relationship between lateral occlusion scheme and dysfunction. According to Yi and Carlsson, CGO, GFO, and BBO were not related to dysfunction development.[21] The other studies confirmed that for asymptomatic individuals, the lateral occlusion scheme can be altered without causing patient discomfort or dysfunction development. This applies to CGO and GFO and for tooth- and implant-supported prostheses. Although the patient might be aware of the occlusion alteration, patient adaptation was reported after a brief period following prostheses insertion (a few weeks to a few months).[19,20,22,24] However, patient awareness of the alteration has been primarily attributed to the increase of the OVD. This has been clearly demonstrated by Sierpinska et al[25] who found that following an increase of OVD, the EMG activity of masticatory muscles had reduced immediately. Following a 3-month period, the EMG activity was restored pretreatment EMG activity levels. This finding also supports that the altered EMG activity detected by the earlier studies is due to experimental design with no true clinical significance, and the EMG activity might be restored to closer to base line record.

The outcome of this review supports that there is no causative relationship between the lateral occlusion scheme and TMD development. This finding is in accordance with the multiple logistic regression analysis that found occlusal factors were related to TMD development in only 15% of patients.[55] Furthermore, Seligman and Pullinger[56] established that altering the occlusal variable is not necessarily associated with TMD developments. Likewise, the current state of evidence indicates that occlusal treatment will not prevent or treat TMD. Instead, nonocclusal treatment is considered more justifiable and conservative.[57-61] Therefore, altering the occlusion scheme by restoration to solely prevent or treat TMD is not acceptable according to the current level of evidence.

In addition, this review cannot find a clear relationship between the lateral occlusion scheme and mechanical complications of the restorative treatment for tooth supported restoration or prosthesis. CGO and GFO appear to have a satisfactory outcome for composite resin restorations and for fixed prostheses for up to 5 years. For composite resin, restoration degradation was observed in relation to wear, surface roughness, marginal integrity, and staining.[26-31] However, this is not necessarily related to the occlusion scheme. Instead, it appears to be related to the restorative material, which is in accordance with other clinical trials.[62,63] Hemmings et al[28] found the success was dependent on the composite resin brand. Likewise, Redman et al[29] found the marginal fracture was affected by the composite resin materials used. Other than the occlusion scheme, bruxism appears to contribute to the failure rate of the composite restorations.[29] Therefore, a relationship between restoration/prosthesis longevity and lateral occlusion scheme cannot be established at this stage. Preferably, this relationship should further be validated by a comparative long-term clinical trial.

Biomechanically, implant-supported prosthesis differs from tooth prosthesis in the lack of the periodontal ligament and its proprioceptive capabilities.[64] Several authors confirmed that teeth are more sensitive in detecting occlusal interferences than implants.[65,66] In addition, the cushioning effect of the periodontal ligament will render the tooth 20 times more mobile than the implant.[64]

Therefore, it is expected that the risk of overloading is greater for implants than teeth. However, whether altering the occlusion scheme will cause a significant overloading of the implants is yet to be answered. Furthermore, it is not yet known if the occlusion on oral implants should be different from that of teeth.[67]

For fixed dental prosthesis supported by implants, there are some signs that GFO is associated with greater mechanical complications in the form of ceramic chipping than CGO.[23] However, the authors did not attribute the increased rate of ceramic chipping to the GFO. In general, for implant prostheses, it is recommended to alleviate the implant prosthesis from lateral contacts during excursion and maintaining contacts on natural teeth,[64,68] which is envisaged to minimize the nonaxial loading of implant components and put them at greater risk for mechanical failure through micromovement or flexure.[68] Thus, CGO would be beneficial to alleviate the contacts on posterior implant prostheses. Conversely, with more extensive implant prostheses, it is difficult to alleviate all of the implant prostheses from lateral contacts during excursion, which mandates GFO. However, systematic reviews revealed that a multi-unit implant prosthesis has a tendency to have more mechanical complications than a single implant prosthesis.[69] For example, over a period of 5 years, the incidence of ceramic veneer fracture was 3.5%[70] for single implant prosthesis and 13.5% for fixed dental prosthesis.[71] The effect of the prosthesis extension could contribute to the observed difference in incidence of ceramic chipping. Still, the implication of the lateral occlusion scheme on major complications, such as screw complications, implant fracture, and components fracture, is yet to be investigated. Therefore, the current evidence does not answer the question of whether the implant occlusion should differ from natural teeth occlusion or not.[67] More critically contributing factors to veneer complications are the presence of bruxism and the opposing occlusion. There is an agreement between the 2 included studies that bruxism and opposing prosthesis supported by implants contribute to the increased incidence of veneer chipping.[23,24] Therefore, a recommendation was made to wear an occlusal splint for protection against the parafunctional activities. It is very likely that the lateral occlusion scheme is a less critical factor for implant overloading than the parafunctional activities or opposing dentition.

Ideal lateral occlusion scheme

This systematic review revealed that although the different lateral occlusion schemes illicit different immediate responses, the long-term effect of any scheme cannot be confirmed. Because the long-term studies have confirmed that patients with CGO or GFO can function comfortably, a benchmark lateral occlusion scheme cannot be proposed, as stated by earlier reports.[4,5] This also fits with a recent systematic review that reports a significant variation of the lateral occlusion scheme for the physiologic nonrestored dentition and that a genuine lateral occlusion scheme rarely occurs naturally.[53] This supports the view that the impact of the lateral occlusion schemes was overrated in the earlier literature.[72] Consequently, in accordance with several investigators, it is recommended to implement flexibility and broader principles in occlusion design.[4,5,53] Therefore, as a clinical guide, instead of adhering to a preconceived occlusion scheme when complex restorative treatment is indicated, the clinician should consider an occlusion scheme that is practical, simple, conservative, and allows esthetic treatment.[4,72-74]

The current state of evidence does not provide information about the effect that lateral occlusion has on different restorative parameters. For example, knowledge is scarce about the effect of lateral occlusion scheme on periodontally and endodontically compromised abutment teeth. Furthermore, there is no information about the response of restorative materials to different lateral occlusion schemes. Several authors have mentioned that there is no implant-specific occlusion, and the lateral occlusion scheme for implant prostheses should not necessarily deviate from the occlusion scheme on tooth supported prostheses.[64,68] It is very desirable that the effects of the lateral occlusion scheme on different restorative variables be evaluated by randomized controlled trials.

Nevertheless, after scrutinizing the current evidence, it might be possible to confirm some reasonable guidelines. Three key features should be incorporated in any lateral occlusion scheme for prosthesis design: (1) long centric (2) disclusion induced by morphologies, and (3) lack of balancing side contacts and interferences.

A feature of the natural dentition is maintenance of numerous tooth contacts after a partial excursion of 1 to 1.5 mm. Therefore, it was stated that the incidence of GFO is much higher than CGO after partial excursion.[53] This fits with the recommendation of several authors regarding freedom of movement of centric occlusion, where teeth contacts are maintained with mandibular lateral movements of 1 mm.[75-77] The proposal was that such a design will allow smooth and multidirectional freedom of mandibular movement and enhanced patient comfort.[7] In addition, such morphology will centralize the occlusal forces vertically to the apical direction and reduce the lateral forces and bending moments.[78] Furthermore, the possibility of introducing premature occlusal contacts is reduced. On the contrary, constricted movement and immediate disclusion is expected to manifest in greater patient awareness and an increase of lateral forces on the dentition.[6,75,78]

From the long-term studies included in this review, it appears that CGO and GFO are equally acceptable. CGO has a practical advantage of being easier to produce than GFO. Furthermore, CGO might be a useful option if the canines are in excellent condition,[21] which allows them to cope with heavy lateral forces. However, it is also acknowledged that occlusion is rather dynamic and has a tendency to change with time. With aging and tooth wear, the prevalence of GFO is increased accordingly whether the dentition is natural[79] or restored.[21] Therefore, it might be useful to design the occlusion to allow GFO development following canine wear.

In line with many recommendations, balancing contacts are better to be avoided.[4,64] Although they frequently occur naturally and clinical evidence about their negative consequences is still lacking,[72] achieving evenly balancing contacts is rather impractical and difficult without introducing interferences. Furthermore, there is no genuine advantage that can justify their introduction, although they might develop after settling of the prosthesis.[21]

CONCLUSIONS

Within the limitations of this review, the following can be concluded:

1. There are some differences between the different lateral occlusion schemes in relation to parafunctional muscle activities and the magnitude of mandibular movement. However, physiologic function and patient acceptance appear to be minimally influenced by the lateral occlusion scheme. Nevertheless, the clinical significance of the reported differences cannot be confirmed since the long-term studies have confirmed the suitability of CGO and GFO.
2. CGO or GFO are equally acceptable when restoring dentition. Multidirectional freedom of mandibular movement appears to be physiological. The evidence supports a flexible principle of occlusion rather than a preconceived occlusion theory.
3. Similar lateral occlusion principles can be considered for implant prosthesis.

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Corresponding author:
Dr Jaafar Abduo
Melbourne Dental School
Melbourne University
720 Swanston Street, Melbourne
Victoria 3010
AUSTRALIA
Email: jaafar_abduo@hotmail.com