

Application of the Functionally Generated Path Technique to Restore Mandibular Molars in Bilateral Group Function Occlusion

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The functionally generated path (FGP) is a static representation of the opposing cusps' dynamic eccentric movements from a centric position to achieve optimal articulation and occlusal harmony. The FGP technique is capable of recording such eccentric movements at the correct occlusal vertical dimension (OVD), as the eccentric movements are influenced by both the anterior guidance and the condylar guidance. Initially, Meyer¹ discussed the "functional occlusal path" as the harmonious relationship between the occlusal and cuspal paths, the condylar paths, and the neuromuscular system. Pankey and Mann² adapted the principles discussed by Meyer¹ to describe a "functionally generated path" record in the fabrication of maxillary restorations. Dawson³ states the lateral eccentric movements of

Abstract

The functionally generated path (FGP) is a static representation of the opposing cusps' dynamic eccentric movements from a centric position to achieve optimal articulation and occlusal harmony. When understood and appreciated, use of the FGP technique is a straightforward and practical method to achieve harmonious occlusal anatomy of restorations with the anterior determinant/anterior guidance, the posterior determinant/condylar guidance, existing occlusal and cuspal anatomy, and the neuromuscular system. Although the FGP technique is normally used in the fabrication of maxillary posterior indirect restorations that maintained the patient's bilateral group function occlusion while eliminating the nonworking side and protrusive interferences. This novel procedure involved the use of a stone crib to intraorally construct a stone core that captured the FGP recording while simultaneously indexing to the contralateral and ipsilateral mandibular dentition. This technique lends additional stability to the stone core to minimize error during the mounting process.

the mandibular posterior dentition are established by an anterior determinant and a posterior determinant. The anterior determinant is the anterior guidance, while the posterior determinant is the condyle-disk anatomical relationship limiting mandibular movement,³ also termed condylar guidance. When understood and appreciated, use of the FGP technique is a straightforward and practical method to achieve harmonious occlusal anatomy of restorations with the anterior determinant/anterior guidance, the posterior determinant/condylar guidance, existing occlusal and cuspal anatomy, and the neuromuscular system.

The FGP technique has been used in the fabrication of complete dentures,^{1,4} oral rehabilitation cases,^{2,4,5} tooth-supported fixed dental prostheses (FDPs),^{6,7} implant-supported

FDPs,⁸ single-unit indirect restorations,⁹ and computer-aided design/computer-aided manufacturing (CAD/CAM) restorations.¹⁰ The FGP technique was initially associated with bilateral balanced occlusion in complete dentures, but may be used in group function occlusion or mutually protected articulation.

The FGP technique is normally used in the fabrication of maxillary posterior indirect restorations, but is described and applied here in the fabrication of bilateral mandibular molar full-gold crowns. The case described here involves a patient with bilateral group function occlusion, an Angle Class II orthodontic relationship, 12 to 13 mm anterior overiet not able to be restored in centric relation (CR) for the purpose of achieving anterior-posterior coupling, and symptomatic bilateral mandibular molar complete and incomplete crown fractures. Teeth #19 and 30 presented with large occlusal amalgam restorations and thin, unsupported tooth structure of the marginal ridges. Tooth #19 presented with a distal-buccal complete, uncomplicated cusp fracture. Tooth #18 presented with an occlusal amalgam restoration and #31 with an occlusalbuccal amalgam restoration. There were right-side nonworking contacts of teeth #2-31, left-side nonworking contacts of teeth #15-18, and protrusive contacts of teeth #3-31, 7-26, 11-22, and 14-19. The patient presented with no signs or symptoms of temporomandibular disorder.

Dawson³ and Shillingburg et al¹¹ note the following prerequisites for use of the FGP:

- 1. Presence of optimal occlusion.
- 2. Correct anterior guidance.
- 3. Absence/elimination of posterior interferences.
- 4. Adequate opposing occlusal surfaces capable of generating a functional path: no significant rotations, no carious lesions, no deficient restorations.

In this case, however, the patient did not have optimal occlusion, did not have anterior guidance, and had posterior interferences in nonworking and protrusive eccentric movements. Without comprehensive orthodontic treatment and orthognathic surgery these requirements were unable to be met.

Therefore, it was necessary to maintain the patient's initial occlusal scheme and restore in bilateral group function occlusion, harmonizing bilateral group function with the other teeth in the same quadrant while eliminating nonworking and protrusive interferences. Teeth #18, 19, 30, and 31 were prepared for full-gold crowns in the usual manner. A recording table was used to capture the maximal intercuspal position (MIP) and eccentric movements of the maxillary opposing cusps in FGP wax. A stone crib was used to construct a stone core intraorally capturing the FGP recording of teeth #18, 19, 30, and 31 while simultaneously indexing to the contralateral and ipsilateral mandibular dentition. The case was mounted in MIP on a Whip-Mix articulator (Whip Mix, Louisville, KY), and full contour waxings were completed against the stone core and verified against the anatomic cast. The full-gold crowns were fabricated to achieve B and C occlusal contacts12 in MIP with working side contacts, but the nonworking contacts and the protrusive contacts were eliminated by exploiting the recorded pathway. Because the stone core was fabricated intraorally, reducing the potential mounting error to the master cast, the patient was restored in bilateral group function occlusion with the final mandibular posterior restorations requiring minimal occlusal adjustment clinically.

Technique

Following initial evaluation, diagnosis, and treatment planning, the fabrication of #18, 19, 30, and 31 full-gold crowns was completed during four separate appointments. At the first appointment, teeth #30 and 31 were prepared for full-gold crowns with recording of the FGP. The crowns for #30 and 31 were then delivered at the second appointment. At the third appointment, teeth #18 and 19 were prepared for full-gold crowns with recording of the FGP. The crowns for #18 and 19 were then delivered at the fourth appointment. The same FGP technique was used to fabricate #18, 19, 30, and 31 full-gold crowns, but the method and photographs will describe the process for #18 and 19.

- 1. A stone crib (a platform designed to provide stability of the slurry stone bulk when constructing the stone core intraorally) was fabricated using custom tray material (Triad^{\mathbb{R}}) TruTrayTM; Dentsply Trubyte, York, PA) on a mandibular diagnostic cast (Fig 1A). The stone crib allowed indexing of the stone core to the unprepared teeth in the mandibular arch while capturing the FGP recording without removing the recording table/FGP recording intraorally. The stone crib also restricted the flow of stone into the floor of the mouth. The stone crib was made with a rim extending laterally 5 to 7 mm beyond the buccal aspect of the mandibular dentition and covering the tongue space. An opening was prepared in the area of teeth #21-22, #24-27, and #29-30. The intaglio surface of the stone crib was treated with adhesive (VPS Tray Adhesive; Kerr, Orange, CA) and allowed to dry before being relined intraorally with Regisil PB (Regisil[®]PBTM; Dentsply Caulk, Milford, DE) to ensure an intimate seal around the dentition while exposing the occlusal and incisal surfaces (Fig 1B).
- 2. The patient had no contraindications to dental treatment and was anesthetized in the usual manner. Teeth #18 and 19 were prepared for full-gold crowns with a beveled heavy chamfer margin.
- 3. The recording table (a platform designed to support the FGP wax during recording) was fabricated directly on prepared teeth #18 and 19 using a bis-acryl interim material (Integrity[®]; Dentsply Caulk) with a putty matrix normally used to fabricate an interim crown (Reprosil[®] VPS; Dentsply Caulk) stabilized with custom tray material (Triad[®] TruTrayTM; Dentsply Trubyte) (Fig 2). The putty matrix was previously fabricated on a cast of unprepared teeth #18 and 19 after baseplate wax (NeoWax[®] baseplate wax; Dentsply Trubyte) was added to the buccal and lingual surfaces of #18 and 19. The purpose of the baseplate wax was to increase the buccolingual dimension of the recording table.
- 4. The recording table was trimmed and adjusted to fit prepared teeth #18 and 19 with good stability and approximately 1 to 2 mm interocclusal space (Fig 2). Multiple 1 to 2 mm grooves were prepared on the occlusal aspect of the recording table, and a thin layer of Sticky Wax (Kerr



Figure 1 Stone crib fabricated on mandibular diagnostic cast (A) and relined intraorally (B).

Figure 2 Recording table fabricated intraorally using a putty matrix.

Lab – Sybron Dental Specialties, Orange, CA) was applied to the occlusal aspect of the recording table for additional retention of the FGP wax. The stone crib was placed intraorally to verify no interference with the recording table (Fig 3).

- 5. The recording table was replaced on prepared teeth #18 and 19. The FGP wax (compounded by the prosthodontic residency program; Lackland AFB, TX) was placed onto the occlusal aspect of the recording table. The FGP recording was made (Fig 4) by guiding and instructing the patient into MIP and eccentric movements as follows:
 - First, the patient closed into MIP.
 - The patient then moved from MIP to a lateral working position and back to MIP.
 - The patient then moved from MIP to a lateral nonworking position and back to MIP.
 - The patient then moved from MIP to a protrusive position.
 - These movements were repeated.
 - The patient was then instructed to move through all the potential eccentric position combinations and back to MIP.
 - During the MIP and eccentric positions/movements, the patient moistened the opposing maxillary dentition with saliva to act as a lubricant.



Figure 3 Verification of no interference between the stone crib and recording table.

Following the FGP recording, the wax was evaluated for continuity and a smooth surface replicating the movements of the opposing maxillary cusps.

6. The recording table with the FGP wax recording was retained on the prepared teeth, while the stone crib was then placed on the mandibular arch (Fig 5A). A slurry of type IV dental stone (Snap-Stone; Whip Mix) was mixed and gently applied via hand vibration using a mixing spatula onto the FGP wax recorded surface and the exposed



Figure 4 FGP wax recording in MIP (A), working (B), nonworking (C), and protrusive position contacts (D).

Figure 5 Placement of stone crib with retained recording table/FGP wax recording and intraoral fabrication of stone core using a slurry dental stone.

incisal/occlusal surfaces of the unprepared mandibular teeth (Fig 5B). Additional slurry stone was then applied for bulk and strength to create the stone core. The slurry stone was allowed to set intraorally prior to removal.

- 7. The stone core and stone crib were removed from the oral cavity as one piece (Fig 6). The stone core was evaluated to ensure accurate capture and representation of the FGP wax recorded surface and proper indexing to the ipsilateral and contralateral teeth.
- 8. A mandibular full-arch impression was made with vinylpolysiloxane (VPS) material (Aquasil Monophase type 2 and Aquasil Ultra XLV type 3; Dentsply) using a stock tray. An MIP interocclusal record was made between the prepared teeth and the opposing maxillary dentition with Regisil[®]PBTM; (Dentsply Caulk). Interims for teeth #18 and 19 were fabricated with Integrity[®] (Dentsply Caulk) and cemented with Temp-Bond NE (Kerr).
- 9. The mandibular VPS impression was poured in type V dental stone (Die-Keen[®]; Heraeus-Modern Materials, South Bend, IN). The mandibular master cast was cross-mounted in MIP using an interocclusal record (Regisil[®]PBTM) to a maxillary cast previously mounted using a facebow transfer on a Whip Mix articulator (2000 Series Articulator; Whip Mix Corporation). The stone core was then related to the mounted mandibular master cast using the index to the unprepared incisal/occlusal surfaces and mounted to the upper member of the articulator (Fig 7). The mandibular

lar master cast was prepared for fabrication of the full-gold crowns.

 Full contour waxings of #18 and 19 full-gold crowns (Fig 8A, B) were completed as follows:

B

- A lubricant (GatorTM Die Lube; Whip Mix) was applied to the FGP area of the stone core.
- The occlusal surfaces of #18 and 19 were initially waxed to the stone core ensuring accurate adaptation to the FGP area.
- The occlusal surface of the waxings was slightly modified to establish cusps and grooves resembling occlusal anatomy. Wax was removed where there was evidence of lateral nonworking contacts.
- The waxings of #18 and 19 were completed by articulating the anatomic cast with the mandibular master cast to ensure B and C occlusal contacts in MIP with no change to the OVD.

The full-gold crowns were invested (Beauty-Cast Gypsum Investment; Whip Mix) and cast using type III gold (Firmilay[®]; Jelenko, Hannover, Germany) (Fig 8C, D).

11. Clinically, the intaglio surfaces of the crowns were evaluated and adjusted using Disclosing Wax (Kerr) before evaluation of the occlusion and proper proximal contacts. Minimal adjustment was required on the occlusal surfaces to attain B and C occlusal contacts in MIP with working



Figure 7 Mounting of the stone core to mandibular master cast—note the capture of the FGP wax recorded surface and simultaneous index to the ipsilateral and contralateral dentition.

position contacts consistent with the other teeth in the posterior quadrant. Nonworking position contacts and protrusive contacts were evaluated to have no contacts using shimstock (Artus Occlusal Registration Strips; Artus, Englewood, NJ).

- Ultimately, the patient was restored in a bilateral group function occlusal scheme. The crowns were cemented with a resin-modified glass ionomer luting cement (RelyXTM Luting Plus; 3M ESPE, St. Paul, MN) (Fig 9).
- 13. Maxillary and mandibular alginate impressions (Jeltrate[®] Alginate Impression Material; Dentsply Caulk) and an interocclusal record in CR (Regisil[®]PBTM; Dentsply Caulk) were made. An occlusal device was made (Eclipse[®]; Dentsply). The occlusal device was delivered and adjusted in CR with a mutually protected occlusal scheme. The patient was instructed to wear the occlusal device during sleep.

Discussion

The authors believe that the FGP technique described here is a novel method to fabricate mandibular molar crowns when no distal tooth is present to index a stone core. A stone core indexed to the contralateral and ipsilateral mandibular teeth was necessary as teeth #18, 19, 30, and 31 were prepared, and teeth #17 and 32 were not present. A unique application was the use of a stone crib. The stone crib retained the slurry stone in a position that captured the FGP recording and simultaneously indexed to the contralateral and ipsilateral mandibular dentition via the incisal/occlusal openings. This method produced a stable stone core and reduced potential error when mounting the case. A crucial step was relining the intaglio surface of the stone crib with a registration material to prevent the slurry stone from engaging undercuts, thereby making removal from the oral cavity difficult.

The fabrication of mandibular molar crowns described here is itself a unique application of the FGP technique because three of the four prerequisites for use of the FGP according to Dawson³ and Shillingburg et al¹¹ were not met: the patient did not have optimal occlusion, did not have anterior guidance, and had posterior interferences in nonworking and protrusive eccentric movements. The patient presented with bilateral group function occlusion, an Angle Class II orthodontic relationship, 12 to 13 mm anterior overjet not able to be restored in CR for the purpose of achieving anterior-posterior coupling, and symptomatic bilateral mandibular molar complete and incomplete



Figure 8 Full-contour waxings (A, B) and fabrication of #18 and 19 full-gold crowns (C, D).



Figure 9 Definitive restorations #18, 19, 30, and 31 using the FGP technique described—note the harmonious occlusion #18 and 19 in MIP and working position to maintain the patient's group function occlusal scheme.

crown fractures. The patient was unable to achieve end-to-end contact of the maxillary and mandibular anterior dentition due to the 12 to 13 mm overjet. As previously mentioned, the pre-requisites described by Dawson³ and Shillingburg et al¹¹ could not be met without comprehensive orthodontic treatment and orthognathic surgery.

It is important to ensure the patient moves to the most lateral eccentric position when recording the FGP. If the patient moves in a protruded lateral eccentric position instead of a pure lateral movement, interferences may result.

The FGP recording wax used was locally compounded by the prosthodontic residency program at Lackland AFB, TX. Other waxes that may be used for FGP recording include Kerr Korecta wax and Bosworth Synthetic Tackywax. The FGP wax needs to be accurate and able to maintain the FGP recording until the stone core is fabricated. The FGP wax should remain in a soft stage throughout the lateral eccentric positions so movement is not restricted. The recording table used was stable, retentive, and did not affect the tooth preparations. Other terms for the recording table include acrylic base, recording base, or wax platform. The term "stone crib" was used to describe the appliance for constructing the stone core and, to the authors' knowledge, is not known by another term. The term "stone core" was used—other terms include functional core, stone counter, functional index, or counter die.

A Whip Mix articulator (class III, semi-adjustable) was used to mount the case, as it was readily available. Any articulator capable of accurate opening/closing with a vertical stop could be used to mount the case, including a simple hinge articulator (class I or II, nonadjustable) not capable of lateral eccentric movements such as a Verticulator (JF Jelenko; Armonk, NY) or Twin-Stage Occluder (Teledyne Hanau; Buffalo, NY). Normal waxing methods and crown fabrication methods may be used with the FGP technique. The waxings were accomplished opposing the mounted stone core, then the occlusal surfaces of the waxings were slightly modified to establish cusps and grooves resembling occlusal anatomy. Wax was removed where there was evidence of nonworking contacts. The anatomic cast was used secondly to verify B and C occlusal contacts of the waxing in MIP and ensure the general buccolingual contours were harmonious with the remaining teeth; however, Schillingburg et al¹¹ advocate waxing to the anatomic cast first and using the stone core to complete the waxing. A misconception exists that suggests the FGP technique may produce a flat occlusion or the appearance of a worn occlusion. But with an accurate stone core, attention to detail, and understanding what the objective is, the FGP technique can produce a relatively normal occlusal anatomy in a harmonious relationship with the existing occlusal scheme. Although the buccal cusp height of #18 and 19 fullgold crowns was decreased, the stability of the restorations was maintained with B and C occlusal contacts in a group function occlusal scheme.

Summary

The FGP is a static representation of the opposing cusps' dynamic eccentric movements from a centric position to achieve optimal articulation and occlusal harmony. When understood and appreciated, use of the FGP technique is a straightforward and practical method to achieve harmonious occlusal anatomy of restorations with the anterior determinant/anterior guidance, the posterior determinant/condylar guidance, existing occlusal/cuspal anatomy, and the neuromuscular system. Although the FGP technique is normally used in the fabrication of maxillary posterior indirect restorations, it was described and applied here in the fabrication of bilateral mandibular molar full-gold crowns due to the patient's presenting orthodontic relationship and occlusal scheme. The FGP technique described here was applied to a difficult clinical situation in which routine restorations would likely result in iatrogenic interferences. The novel FGP technique described produced restorations with relatively normal occlusal anatomy, required minimal chairside occlusal adjustment, and were harmonious with the patient's existing bilateral group function occlusal scheme.

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References

- Meyer FS: The generated path technique in reconstruction dentistry. Part I: complete dentures. J Prosthet Dent 1959:9:354-366
- Pankey LD, Mann AW: Oral rehabilitation. Part II: reconstruction of the upper teeth using a functionally generated path technique. J Prosthet Dent 1960;10:151-162
- Dawson PE: Functionally generated path techniques for recording border movements intraorally. In Dawson PE (ed): Evaluation, Diagnosis, and Treatment of Occlusal Problems. St. Louis, Mosby, 1989, pp. 410-433
- Meyer FS: A new, simple and accurate technique for obtaining balanced and functional occlusion. J Am Dent Assoc 1934;21:195-203
- 5. Mann AW, Pankey LD: Oral rehabilitation utilizing the Pankey-Mann instrument and a functional bite technique. Dent Clin N Am 1959;3:215-230
- Meyer FS: The generated path technique in reconstruction dentistry. Part II: fixed partial dentures. J Prosthet Dent 1959;9:432-440
- Prashanti E, Sajjan S, Reddy JM: Fabrication of fixed partial dentures using functionally generated path technique and double casting. Indian J Dent Res 2009;20:492-495
- Sutton AJ, Sheets DW Jr., Ford DE: Fabrication of a functionally generated, implant-retained fixed partial denture. J Prosthodont 2003;12:260-264
- Engelman MA, Engelman CL, Zamaloff V: Use of the functionally generated path to establish precise occlusion in restorative dentistry. Quintessence Int 1983;14:799-811
- Sohmura T, Takahashi J: Use of CAD/CAM system to fabricate dental prostheses. Part 1: CAD for a clinical crown restoration. Int J Prosthodont 1995;8:252-258
- Schillingburg HT Jr., Hobo S, Whitsett LD et al: The functionally generated path. In Schillingburg HT Jr., Hobo S, Whitsett LD et al (eds): Fundamentals of Fixed Prosthodontics (ed 3). Carol Stream, IL, Quintessence, 1997, pp. 355-364
- International Academy of Gnathology, Glossary Committee: the glossary of occlusal terms [Internet]. International Academy of Gnathology, American Section; September 1985 Available from: http://www.gnathologyusa.org/got_a-q.html. Accessed July 16, 2012

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