Impact of kinematics on the efficiency and safety of an engine-driven file for glide path preparation in MB2 canals of maxillary molars

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Research Article

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Abstract

Introduction:

To evaluate the influence of different kinematics on the efficiency and safety of an engine-driven file for glide path preparation in second mesiobuccal canals (MB2) of maxillary molars. In addition, the torsional resistance of the file was assessed after use.

Methodology:

Thirty-six maxillary first and second molars with two canals in the mesiobuccal root were selected and the anatomy of the canals was verified by micro-CT. The teeth were divided into 4 groups (n = 9) according to the kinematics used for glide path preparation: continuous rotation (CR), 30°/150° reciprocation (REC 30°/150°), 30°/90° reciprocation (REC 30°/90°), and 90° optimum glide path motion (OGP 90°). The duration of the procedure, number of canals in which the file reached the full working length (RFWL), canal volume before and after the procedure, rate of file fracture, and file torsional strength after use were evaluated. The ANOVA and Tukey tests or Kruskal-Wallis and Dunn tests were used for statistical analysis.

Results

No significant differences among the groups were found for procedure duration, success at reaching the FWL, distance from the file to apex, and number of fractured files ($P > 0.05$). The CR group showed a significant decrease in rotation angle compared with REC 90° and OGP 90° groups ($P < 0.05$). There was no significant difference in canal volume among the groups ($P > 0.05$).

Conclusion

The type of kinematics used did not affect the efficiency, success rate, and shaping ability of the file during glide path preparation. CR seems to induce more torsional stress than the other kinematics.

Clinical Relevance:

The glide path preparation of narrow canals such as the MB2 is difficult and accidents such as file fracture may occur. This study showed that reciprocation with different file angulations can be safer during this challenging stage.

Introduction

The glide path is a smooth radicular tunnel from canal orifice to physiologic terminus created using a stainless steel no. 10 hand file or an engine-driven file [1–4]. The use of an engine-driven file has several benefits, such as less canal transportation [5–8], lower risk of file fracture [5, 9], less debris extrusion [10, 11], and less postoperative pain [12, 13]. Thus, it is especially recommended for the preparation of curved and narrow canals [2–4].

The engine-driven NiTi glide path files are mainly susceptible to torsional stresses and taper-lock effect [14, 15]. Therefore, manufacturers have developed files with different cross-sections, tapers, tip sizes, heat treatments, and kinematics to improve safety and clinical effectiveness [15–17].

In maxillary molars, there is a high prevalence of second mesiobuccal canals (MB2), which can have significant anatomical variations (canal volume, curvature, calcifications), leading to several difficulties in negotiating and shaping the root canal [18, 19]. Zuolo et al. [20] showed that the use of reciprocating files was 32% more effective than hand files to explore and negotiate MB2 canals of maxillary molars. However, there are no data on the safety and effectiveness of reciprocating or rotary glide path files in negotiating MB2 canals of maxillary molars.

Currently, there are several types of NiTi files specifically designed for glide path preparation with different designs and kinematics [22]. In this study, the Prodesign Logic 15.03 file (Bassi Endo, Belo Horizonte, Brazil) was used. The file has a length of 15 mm (D0), a constant taper of 0.03 mm/mm, a square cross-section, and is made of NiTi CM-Wire Alloy.

Engine-driven glide path files have been previously evaluated by several authors [8, 13, 16, 17], but no study evaluated the impact of different kinematics (continuous rotation, reciprocation, and OGP motion) on their safety and effectiveness. Therefore, the aim of this study was to evaluate the influence of kinematics on the effectiveness and safety of the Prodesign Logic 15.03 file for glide path preparation in MB2 canals, as well as the torsional strength of the file after simulated clinical use. The tested null hypotheses were that the different kinematics do not affect the time spent for glide path preparation, canal volume, success rate, and the file’s torsional properties.

Materials And Methods

Sample size calculation

The sample size was calculated with the G* Power v3.1 software for Mac (Heinrich Heine, Universität Düsseldorf), selecting the Wilcoxon-Mann Whitney test from the T-test family, and defining an alpha error of 0.05, a beta power of 0.8, and an N2/N1 ratio of 1. A total of 7 samples per group were indicated as the ideal size to detect significant differences. Considering the risk of fracture of the file, the sample size was increased by 20%. A total of 9 MB2 canals were used for each group.

Specimen Selection

After the approval of the protocol by the Institutional Research Ethics Committee (protocol: 4,716,078, CAAE: 46099021.2.0000.5417), 36 extracted first and second maxillary molars were selected. Digital periapical radiographs were used to measure the angle and curvature radius of mesiobuccal roots, according to the method proposed by Gu et al. [23]. Roots with curvatures between 10° and 20° and curvature radii between 3 and 5 were selected. Then, the specimens were scanned with a micro-CT system (SkyScan 1174; Bruker-micro-TC, Kontich, Belgium) to select mesiobuccal roots containing MB2 canals with Vertucci type IV configuration.

Micro-ct Scanning And Sample Division

The 36 molars were scanned with micro-CT using the following parameters: voxel size of 19 µm, 50 kV, 800 µA, and 360° rotation around the vertical axis with a rotation step of 0.8° at a resolution of 1024x1304. The obtained images were reconstructed with the NRecon v1.6.9 software (Bruker-micro-TC) and saved in BMP format. Then, the MB2 canals were anatomically paired by calculating the canal volume, diameter, and length using CTAn v1.12 (Bruker-micro-CT). Data were analyzed by Kruskal-Wallis and Dunn tests for sample pairing; no statistical difference was found among the groups ($P > 0.05$). The specimens were randomly divided in 4 groups ($n = 9$), according with the kinematics used for glide path preparation:

Continuous Rotation (CR)

continuous rotation at 350 rpm and torque of 1-Ncm;

30°/150° Reciprocation

150° clockwise (CW) and 30° counterclockwise (CCW) reciprocation at 400 rpm (REC 30°/150°);

30°/90° Reciprocation

90° CW and 30° CCW reciprocation at 500 rpm;

Optimum Glide Path 90°

Optimum Glide Path (OGP) motion at 300 rpm and 90° CW, 90° CCW, 90°CW, and then 120° CCW motions.

Experimental Glide Path Preparation

All experimental procedures were performed by a single previously trained endodontist. After coronal access, the MB2 canal was located with an ultrasonic tip (Helse Dental Technology, Santa Rosa do Viterbo, São Paulo, Brazil) under an Operating Microscope (DF Vasconcelos, Brazil) with a 6x magnification. Then, a no. 8 or no. 10 K file was inserted with low resistance only to determine the correct insertion angle of the canals. Canal irrigation was performed with 2.5% sodium hypochlorite solution (NaOCl) with Navitip gauge 30 needle (Ultradent Products, Inc, South Jordan, UT, USA).

Each tooth was mounted on a specific device (IM do Brazil, São Paulo, SP, Brazil) that simulated the alveolar socket, and the glide path was prepared according to group allocation using the Prodesign Logic 15.03 file. For the continuous rotation and reciprocation groups (30°/150° and 30°/90°) the endodontic motor E-Connect S (MK Life, Porto Alegre, Brazil) was used and for the OGP 90° group, the Tri Auto ZX2 motor (J. Morita MFG, Kyoto, Japan) was used.

The glide paths were prepared as described by De-Deus et al. [17]. The instruments were inserted with a smooth back-and-forth motion with amplitude of about 2 mm until the full working length (FWL) was reached. After three repetitions, the file was cleaned and the canal irrigated with 2 mL of 2.5%sodium hypochlorite. This step was repeated until the file reached the FWL. After three trials, the file was held in position and the apical foramen was examined under a dental operating microscope (DF Vasconcellos SA, Valença, Brazil) at 40x magnification. The canals in which the FWL was reached were recorded, as well as the number of fractured files. The time required for the procedure was recorded with a stopwatch (in seconds), excluding the time used for irrigation. In addition, the canals where the file failed to reach the FWL were radiographed using digital imaging (Microimagem, São Paulo, Brazil) and the distance of the file tip to the canal terminus was measured. Each file was used in 3 canals and then cleaned in saline solution for 3 minutes in an ultrasonic cleaning device (Gnatus, Ribeirão Preto, São Paulo, Brazil).

Micro-ct Analysis

After glide path preparation, the specimens were scanned using the same parameters as the first scan to evaluate the canal volume before and after the procedure. Reconstructed images from before and after the procedure were geometrically superimposed, and the data were compared with the DataViewer software v1.5.2 (Bruker-microCT, Kontich, Belgium). The analysis included the binarization of the root canals and measurement of the volume (mm^3) and surface area (mm^2) of the full canals using CTAn v.1.14.4 [24]. The total canal volume was measured from the root canal orifice to 1 mm short of the apical foramen. Also, the last 4 mm of the apical portion was evaluated. All values were calculated by subtracting the scores for the treated canals from the untreated ones and then converting the values into percentages.

Torsional Fatigue Test

The mean values of torque and maximum angular distortion to failure were determined for the files used in glide path preparation and compared with those of a new file. A total of 8 new files were used.

The torsion test used in this study was described in previous studies [22, 25] and was based on the International Organization for Standardization ISO 3630-1 (1992) using a torsion machine (Analog, Belo

Horizonte, Brazil). The file was fixed by the first 3 mm of the tip with a brass chuck and the engine speed was set at 2 rpm clockwise for all groups. The maximum torsional force and angular rotation to failure were measured.

Statistical analysis

The data were subjected to the Kolmogorov-Smirnov normality test. ANOVA and Tukey tests were used for between-group comparison of procedure duration, number of files at FWL, number of fractured files, and torsion data. Kruskal-Wallis and Dunn tests were used to compare the distance between the file tip and root apex in the specimens where FWL was not reached. The Wilcoxon test was used for within-group comparison of canal volume and the Kruskal-Wallis and Dunn tests were used for between-group comparison. The GraphPad Prism 8 software was used and a significance level of 5% was applied.

Results

The mean and standard deviation of duration (seconds), procedures that reached the FWL (%), and number of fractured files and the median, minimum and maximum values of the file-to-apex distance are shown in Table 1. There were no significant differences among the groups ($P > 0.05$).

Table 1
– Mean ans Standard deviation (SD) of the time required (s) for glide path preparation, absolute frequency and percentage of glide path instruments to reach full working length (RFWL) using different kinematics, median minimum and maximun of the distance values in (mm) from the tip of the instrument to the apical forame. and number and percentage of fractured instruments during glide path preparation

Groups	Time (s) mean ± (SD)	RFWL n | (%)	Distance (mm) Med (Min – Máx)	Fracture n | (%)
CR	27.56 (± 11,0)	8 | (77.8)^{a}	0 (0–2.38)	0 (0.0)^{a}
REC 30/150	21.11 (± 15,30)	8 | (77.8)^{a}	0 (0–5.00)	0 (0.0)^{a}
REC 30/90	26.67 (± 9,32)	8 | (77.8)^{a}	0 (0–0.74)	0 (0.0)^{a}
OGP	35.89 (± 15,91)	8 | (77.8)^{a}	0 (0–5.40)	1 (11.1)^{a}
Different letters in the same column indicate significant difference between kinematics ($P < 0.05$).				

The mean and standard deviation of torque (N.cm) and maximum angular rotation to fracture of the used and new files are shown in Table 2. No significant difference was found among groups for maximum torque to failure ($P > 0.05$), but the maximum angular rotation to failure was significantly lower in the CR group compared with the other groups ($P < 0.05$), except for REC 30°/150° group ($P > 0.05$).

Table 2

Mean and standard deviation of torsion resistance (N.cm) and distortion angle (°) of the instruments subjected to the torsional test after glide path preparation using different kinematics

Groups	**Torque (Ncm) mean ± SD**	**Distortion angle(°) mean ± SD**
New	0.32 ± 0,07	629.4 ± 140.2
CR	0.36 ± 0,05	342.8 ± 25.30 [b]
REC 30/150	0.43 ± 0,13	493.9 ± 110.9 [a,b]
REC 30/90	0.40 ± 0,17	560.7 ± 129.4
OGP	0.40 ± 0,08	672.7 ± 62.07
Different letters indicate significant difference between kinematics and new instruments (P < 0.05).		

The canal volumes before and after glide path preparation are shown in Table 3. The within-groups comparison demonstrated that all kinematics provided a significant increase of total canal volume and volume in the apical portion (P < 0.05). However, there were no significant differences between groups (P > 0.05). Figure 1 shows representative micro CT images of the study groups.

Table 3

The Median, Minimum, and Maximum Values of the Initial, Final Volume and Percentage of Increase in the Total and Apical Volume of the canal according to the kinematics used for glide path preparation

		Total volume (mm³)			**Apical volume (mm³)**	
Group	Initial	Final	% Increase	Initial	Final	% Increase
CR	0.44 (0,36 – 1,07) [,a]	0.73 (0,63 – 1,35) [,b]	63.0 (26.7–93.0)[A]	0.13 (0.06–0.23) [,a]	0.20 (0.13–0.37) [,b]	47.1 (32.6–114.2)
REC 30/90	0.47 (0,42 – 0,83) [,a]	0.78 (0,51 – 1,66) [,b]	38.8 (8.6–72.5)	0.14 (0.04–0.18) [,a]	0.20 (0.14–0.25) [,b]	44.6 (10.4–208.5)
REC 30/150	0.56 (0,28 – 1,08) [,a]	1.10 (0,43 – 1,89) [,b]	70.3 (29.8–239.0)	0.12 (0.07–0.35) [,a]	0.26 (0.14–0,60) [,b]	85.7 (11.0–202.2)
OGP	0.52 (0,06 – 2,09) [,a]	0.75 (0,35 – 4,30) [,b]	105.7 (12.5–438.9)	0.05 (0.02–0.30) [,a]	0.15 (0.09–0.34) [,b]	74.5 (15.2–851.8)
Different lowercase letters indicate significant statistical differences in intragroup comparations for each analyzed group (P < 0.05). Different capital letters indicate significant statistical differences in the group comparisons for each analyzed area (P < 0.05).						

Discussion

The aim of this study was to evaluate the glide path preparation time, success rate, file fracture rate, file torsional properties, and root canal volume using a file in continuous rotation and different reciprocating kinematics.

MB2 canals of maxillary molars were used in this study because the anatomical features of the canals favor great difficulty in negotiating the canals to the apical foramen [18, 19]. These canals tend to have a tortuous trajectory, different curvatures, and calcifications [19], increasing the risk of file separation [18–20]. Thus, the preparation of MB2 canals is challenging.

The samples used in this study were selected through micro-CT to ensure anatomical similarities in canal configuration, curvature, and length. The initial canal volumes were analyzed statically to ensure similar conditions among groups (Table 3) and reduce the risk of bias. Despite these strict measures, one of the limitations of this study was that root canals were not very similar in all groups.

To further reduce the risk of bias, only one type of file was used in all groups. The design and type of NiTi alloy of the file can modify its mechanical properties and clinical performance, which could affect the study results, as previously reported [25]. In this way, the type of kinematics was the main difference among the groups.

No significant differences were found in glide path preparation time, frequency of files that successfully reached FWL, and number of fractured files, so the null hypothesis was partially accepted. The procedure took longer in the OGP 90° group than in the other groups. It is possible that the lower speed (300 RPM) and more oscillations (90° CW, 90° CCW, 90°CW, and 120° CCW) used in this group demanded more time to the create a glide path. The only file that fractured during the study was from the OGP group, which could be due to an obstruction of the canal, as mentioned earlier.

Few studies evaluated the impact of different kinematics on glide path preparation using one file type [25]. Some authors suggest that a reciprocating motion makes it easier for the file to advance toward the apex without the need for a glide path, thereby reducing the risk of file fracture [20, 26], but our results were similar in all groups. Alcalde et al. [25] found similar results using continuous rotation and 150°-30° reciprocation with a 15.04 glide path file in the mesial root canal of mandibular molars. Most manufacturers strongly recommend inserting a no. 8 or 10 hand file into the canal before using an engine-driven glide path file because it may facilitate the advancement to the apical portion [9, 17]. Therefore, it could be speculated that the rate of files reaching the full working length could be higher if a manual glide path would be created first.

The duration of the procedure was similar in the groups of the present study, which was different from our previous study [25], which found that continuous rotation was significantly faster. The difference in results could be due to the different files used. In this study, a file with a smaller taper (0.03 mm/mm) and made of a CM-Wire NiTi alloy was used, whereas the previous study tested a file made of Blue NiTi Alloy and 0.04 mm/mm taper. The smaller contact area with the canal walls of the file with a smaller taper could result in the file penetrating more easily to the apex [27].

The angular rotation to file fracture differed depending on the kinematics used. High torsional loading during glide path preparation of constricted or narrow canals was also simulated, resulting in the maximum torsional strength and angular rotation of the file to fracture [21–25]. The authors evaluated the torsional properties at the last 3 mm of the file, as this area is more prone to fracture than the 5 mm region [28].

The torsion test was applied to evaluate the effect of kinematics on the torsional properties of the file during the procedure, and the values were compared with those of new files (control groups), as in a previous study [22]. The torsional strength was similar in all groups ($P > 0.05$). However, the angle of rotation to failure was significantly lower in the CR group compared with the other groups ($P < 0.05$), except in the REC- 30°/150° group ($P > 0.05$), but the value of the REC- 30°/150° group was not significantly different from the other groups ($P > 0.05$). The OGP 90° was the only kinematic that did not reduce the angular deflexion values in relation to the values of a new file. The CR was the kinematic that generated the highest torsional stress and significantly reduced the deformation capacity of the file before fracture, followed by the REC- 30°/150° group. In addition, it could be speculated that the OGP 90° kinematic cause the least reduction in the deformation capacity of the file. The continuous rotation kinematic is more prone to taper lock and torsional stresses, as previously reported [17, 21, 25, 29], which is consistent with our results.

The tested kinematics caused similar increases of canal volume and apical volume, indicating similar root canal shaping. All groups presented a significant increase in total canal volume and apical volume. These results confirm those of Pinto et al. [30], who demonstrated that both reciprocating and rotating movements of a file increase canal volume.

Although this was a laboratory study, the results are of clinical relevance. The CR is probably the least safe kinematic to use in a narrow and constricted canal because it leads to a reduction in the deformation capacity of the file and consequently to a higher risk of fracture. Therefore, future clinical studies should be conducted to confirm our results.

Conclusions

In conclusion, within the limitations of this study, the type of kinematics did not impact the efficiency and success rate of glide path preparation of MB2 canals using the Pro Design Logic 15.03 file. The continuous rotational movement generated greater torsional stresses during the procedure.

Declarations

Conflict of Interest:

The authors have no conflicts of interest related to this study.

Ethical approval:

This study was previously approved by the Institutional Research Ethics Committee (protocol: 4,716,078, CAAE: 46099021.2.0000.5417) and was in accordance with the ethical standards of the institutional and/or national research committee for human research

Informed consent:

This study did not involve participants.

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AUTHOR CONTRIBUTION

Larissa B. B. Araújo - Performed the glide path of all experimental groups

Pedro H. S. Calefi - Performed the mechanical tests of torsional fatigue and collaborated in gilde path timing

Murilo P. Alcalde - Performed the scans on the micro tomography

Giulio Gavini - Performed volume analysis on microtomographic images

Rodrigo R. Vivan - Collaborated in the performance of mechanical tests of torsional fatigue

Marco Antonio Hungaro Duarte - Coordinated, guided and performed the statistical tests of the study

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Figures

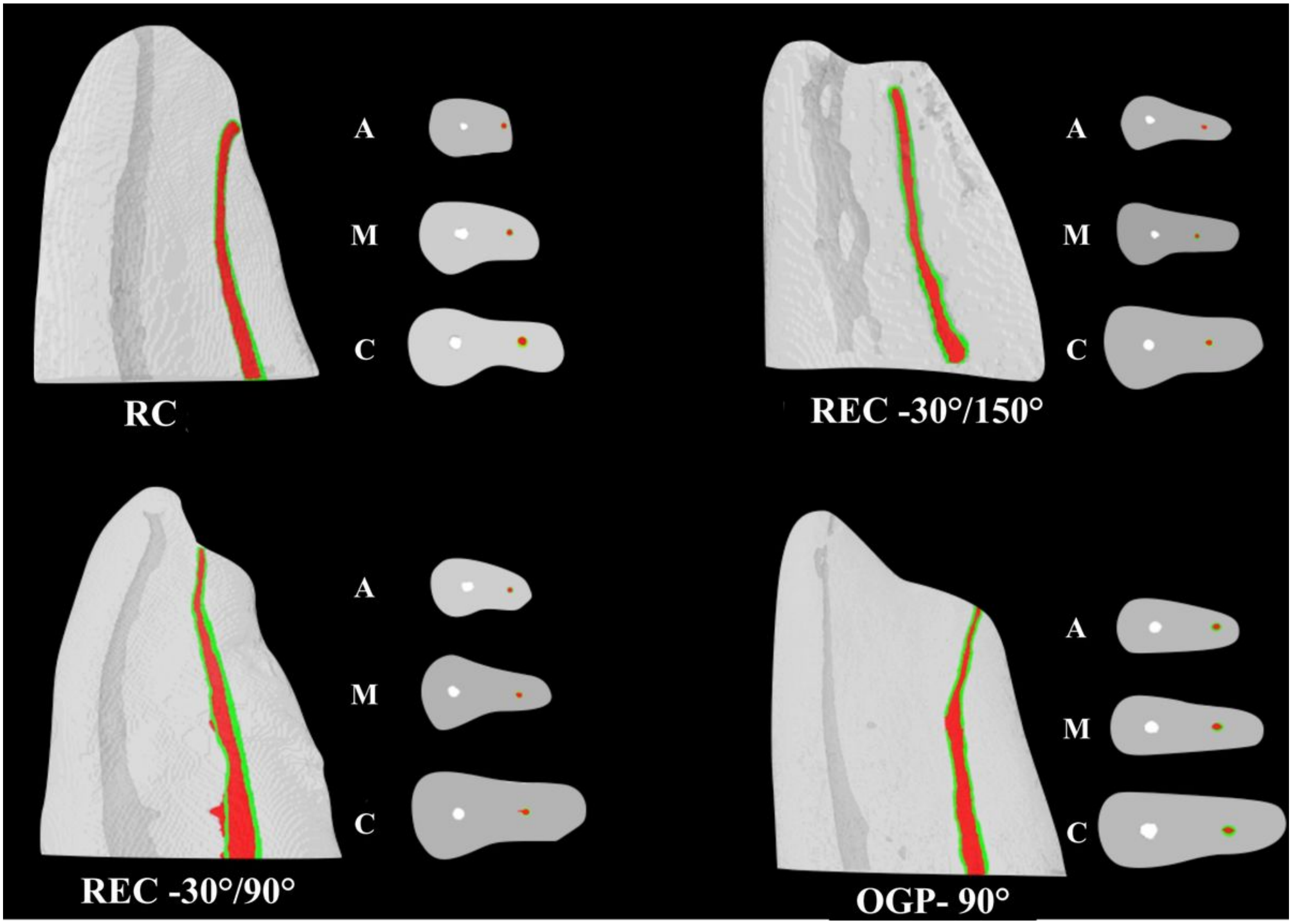

Figure 1

Representative micro- CT image of the studied groups. Red - before glide path creation; Green - after glide path creation.