DIMENSIONAL STABILITY OF 3D PRINTED TOOTH-SUPPORTED IMPLANT SURGICAL GUIDES AFTER AUTOCLAVE STERILIZATION

A Thesis

by

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ABSTRACT

3D printed surgical guides for dental implant placement must be sterilized prior to use for patient safety. It is of clinical interest to know if surgical guides suffer distortion during the sterilization process. However, there is limited data evaluating the distortion resulting from the manufacturer's recommended sterilization protocol.

The purpose of this in vitro study was to evaluate the effect of autoclave sterilization on the dimensional stability of 3D printed tooth-supported implant surgical guides.

Twenty surgical guides were made with 3D printing resin in an SLA printer, and were split into two groups (n=10). Group L consisted of long-span guides including the teeth from first molar to first molar of maxillary arch. Group S consisted of short-span guides including the teeth from canine to canine of maxillary arch. All the guides were designed for placing a single implant at the left central incisor position. No other teeth were missing. After 3D printing, the surgical guides were washed, cured, and the print supports were trimmed. A metal bolt was secured in the guide tube position. After scanning the guides in a laboratory scanner as controls, the guides were sterilized by autoclave according to the resin manufacturer's recommendation (121ºC, 104 kPa, 30 minutes). The post-sterilization scans were aligned either on the bolt or on the cusps to compare with the pre-sterilization scans. For statistical analysis, Mann-Whitney U tests were run on independent samples (α = .05).

There were consistent patterns of distortion typically observed in the apical direction of the teeth. In addition, greater deviations appeared on the distal extensions of group L. When aligning samples on the bolt, there were statistically significant differences of deviations between scans at the distal-most sites of group S and group L ($P < .001$), while there was no significant difference of deviations at the canine sites between two groups ($P = .631$). When aligning samples on the cusps, the group L exhibited significantly greater deviations in bolt angle ($P < .001$) and apical point position ($P < .001$) than those of the group S.

There were significant differences of distortion at the distal-most sites between group L and group S. However, there was no significant difference of distortion up to the canine areas for both groups. Group L demonstrated significant angular distortion of the implant drill guide tube and significant apical location distortion in comparison with group S.

Unnecessary extension of 3D printed surgical guides should be avoided to prevent the potential degree of surgical guide distortion by autoclave sterilization process.

DEDICATION

To my lovely wife.

You are my strength.

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CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supervised by a thesis committee consisting of Dr. Seok-Hwan Cho [committee chair] and Dr. Jenn-Hwan Chen of the Department of Comprehensive Dentistry, and Professor Emet D. Schneiderman of the Department of Biomedical Sciences.

Edits and revisions were suggested by Dr. Seok-Hwan Cho and Dr. Emet D. Schneiderman. All other work conducted for the thesis was completed by the student independently.

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NOMENCLATURE

CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
Group L	Group of long surgical guides
Group S	Group of short surgical guides
MxRFM	Maxillary Right First Molar
MxLFM	Maxillary Left First Molar
MxLC	Maxillary Left Canine
MxRC	Maxillary Right Canine

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INTRODUCTION

3D printing technology known as rapid prototypingor additive manufacturing) is being used more and more in dentistry, with a wide range of materials from plastics, to metals, to organic tissues.[1] Each method and material is unique and needs to be scientifically evaluated for clinical performance. Evidence-based dentistry aims to provide scientific rationale for using methods and materials in the treatment of patients.

Implantology has seen an increase in the use of 3D printing with the fabrication of surgical guides, which were traditionally made by vacuformed thermoplastic splints.[2] Stereolithography (SLA) is a common 3D printing technology to produce implant surgical guides.[3] SLA builds the guides layer-by-layer with a scanning laser which projects into a tank of light-cured photopolymer resin.[1,4] The workflow of designing, planning, manufacturing, preparing, and using guides involves many steps, witch potentially can introduce the inaccuracy of the guided implant placement.[5] In addition to the accuracy of surgical guides, the materials involved must be safe for patients. The substances used to fabricate guides must be biocompatible and suitable for sterilization.[6]

There have been numerous studies evaluating the accuracy of implant placement in guided surgeries, but there is limited literature investigating the dimensional stability of the guides themselves after they have been submitted to the stresses of sterilization.[2,3,7-13] Shaheen et al produced a pilot study evaluating a small sample size of PolyJet 3D printed objects that were not surgical guides. They printed a tooth replica, mandibular cutting guide, and an orthognathic splint. The U-shaped orthognathic splint was unique in their study in that it covered the full arch of teeth and was similar in shape and span to tooth-supported implant surgical guides. They sterilized the objects with gas plasma and steam heat (autoclave) and found that only the splint exhibited morphological distortion after sterilization. It was shown that the distal extensions of the splints exhibited the most distortion with deviations of 1.5-1.7mm, and that the splints were clinically unusable. They also found that steam heat autoclave sterilization caused more distortion than gas plasma.[12] Marei et al scanned and compared surgical guides while mounted on casts with an intraoral scanner before and after sterilization. They found no statistically significant deviations at the center points of the guide sleeves.[9] More studies are needed to determine if guides can be significantly affected in ways that may compromise the accuracy of implant placement.

However, there were no studies comparing distortion due to sterilization between short-span guides and long-span guides. The aim of this study was to evaluate the dimensional stability of short-span (6 units) and long-span (12 units) SLA 3D printed tooth-supported implant surgical guides after autoclave sterilization. The null hypothesis was that no significant differences would be found between the two groups after autoclave sterilization.

MATERIAL AND METHODS

A total of twenty surgical guides were designed in implant planning software (Blue Sky Plan version 4.3.10; Blue Sky Bio, LLC) and edited in 3D mesh editing software (Meshmixer version 3.5.474; Autodesk, Inc.). The guide tube parameters used were those used clinically for 5mm T-sleeve (Straumann Group). Short and long guides were made identical in the inter-canine region, with the long guides extending distally to the first molars. Twenty surgical guides were fabricated by SLA 3D printer (Form 2; Formlabs Inc.) in a 3D printing resin material (Surgical Guide Resin; Formlabs Inc.), which is different from the one Marei et al[9] used in their study, because the resin material was introduced recently. The surgical guides were split into two groups (n = 10). One group (Group L) consisted of long-span guides which covered the maxillary arch from right first molar to left first molar. The other group (Group S) consisted of short-span guides that covered the maxillary arch from right canine to left canine. All the guides were designed for placing a single implant at the maxillary left central incisor position. No other teeth were missing. Figure 1 illustrates the short and long guide designs.

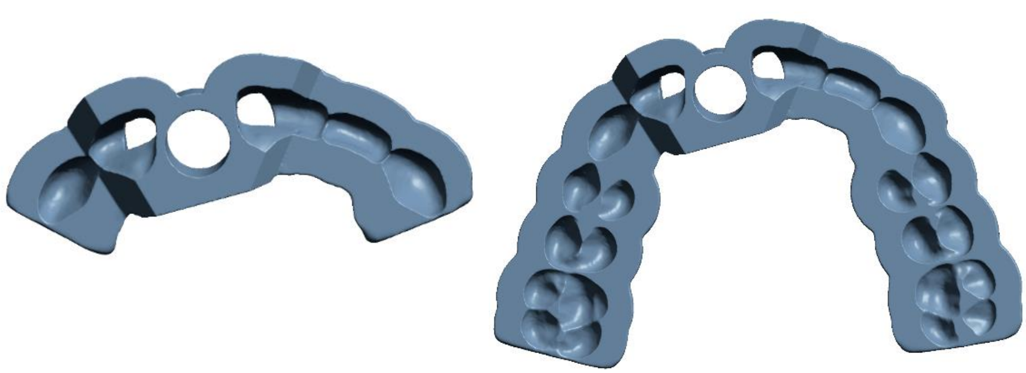

Figure 1. Surgical guide designs. Short guides (left) and long guides (right).

After printing, the guides were washed, cured, and the print supports were trimmed. For each guide, a stainless-steel bolt (6.35mm diameter) was selected that fit securely in the guide tube. The bolt was secured in the guide tube with light-cured resin to serve as an immutable reference between before and after (sterilization) scans. Figure 2 demonstrates how the bolts were inserted and fastened in the guide tubes.

Figure 2. 3D printed surgical guide with stainless-steel bolt secured in the guide tube.

After one week, the guides were coated with a thin layer of powder spray (Scanspray; Renfert Dental Corp) and scanned (control group) in a desktop scanner (D900; 3Shape). Next, the guides were sterilized by autoclave (M11; Midmark) according to the resin manufacturer's recommendation (121ºC, 104 kPa, 30 minutes). After sterilization, the guides were scanned again (test group). The before and after scans were performed within 24 hours of each other.

The post-sterilization scans were aligned and compared with the pre-sterilization scans in CAD inspection software (GOM Inspect 2019; GOM GmbH, and the differences were evaluated qualitatively and quantitatively. For the inspection process, the before and after scans were aligned by two different methods. One method was to align the scans by local best fit on the bolt, which would reveal the distortion of the resin (Figure 3, Left). The other method was to align the scans by local best fit on the resin only in the cusp regions of the teeth, which would reveal the effects on the position of the bolt (Figure 3, Right). In both methods, deviations were measured at selected tooth positions and along the bolt. Color map analysis was evaluated to study the nature of the deviations between the before and after scans, and other software functions were used to measure surface and bolt deviations for statistical analysis (Figure 4).

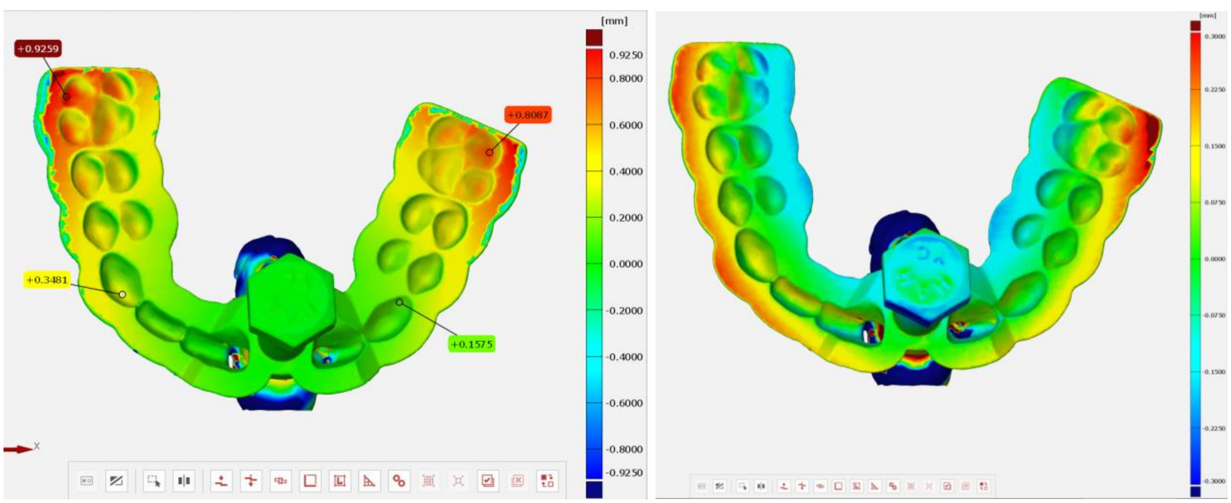

Figure 3. (Left) local best fit alignment based on bolt. Note green regions around bolt and anterior region of guide resin. (Right) local best fit alignment based on cusp regions of resin. Note strip of green color along cusps.

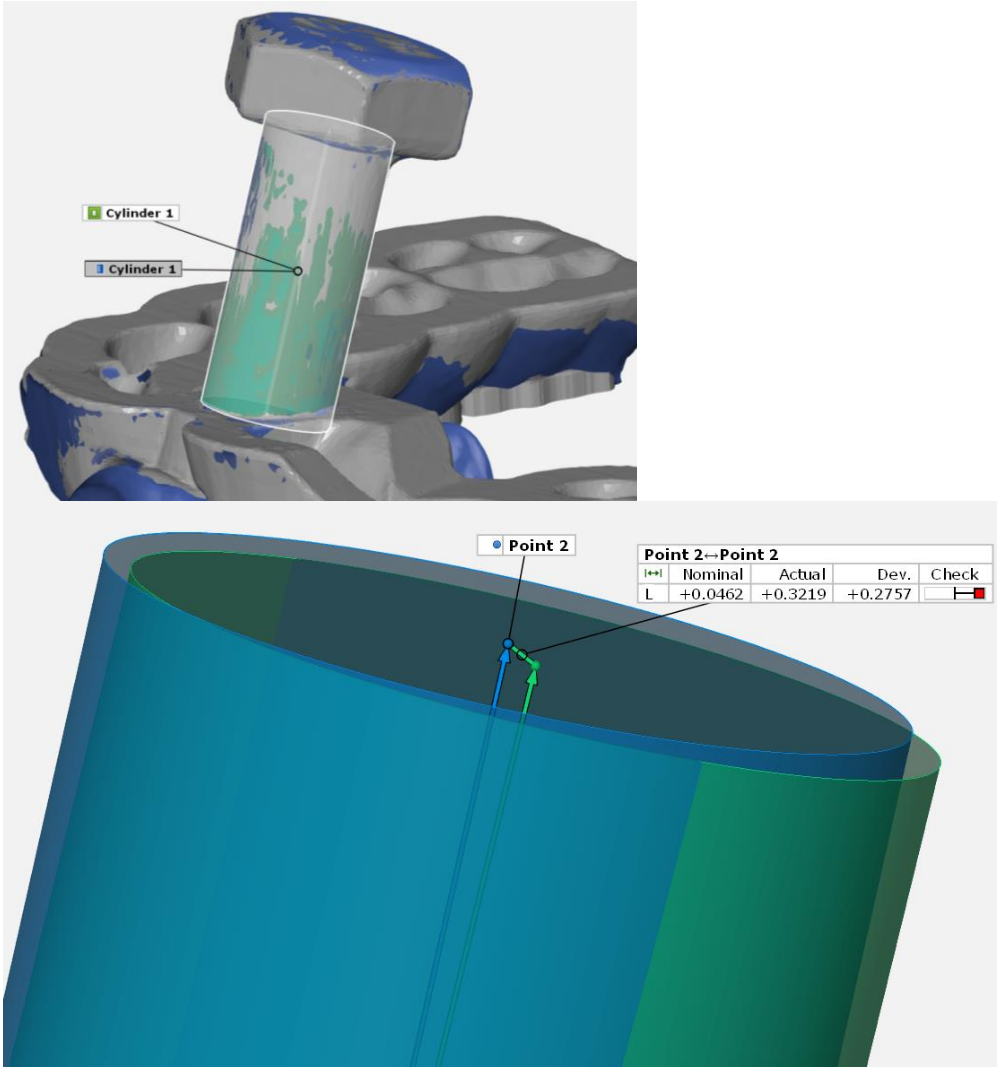

Figure 4. (Above) virtual cylinder constructed along surface of bolt. Cylinder consisted of long axis and end points. (Below) blue and green arrows indicate long axes of cylinder in before (blue) and after (green) scans. Points at ends of arrows are indicate

For the tooth positions in the long guides, measurements were taken at the points of greatest deviation in the distobuccal cusps of the right and left first molars as well as the points of greatest deviation in the cusps of the right and left canines (Figure 3, Left). For the tooth positions in the short guides, measurements were taken at the points of greatest deviation in the cusps of the right and left canines. For all the guides, the difference in bolt angulation was recorded. Additionally, a point was placed at the apex of the bolt, and the difference in position was measured at this location (Figure 4).

The measurement values were recorded in Microsoft Excel and then transferred to IBM SPSS Statistics version 25. Mann-Whitney U tests were run on the two independent groups (α = .05). These nonparametric tests were used as the variables of interest were not normally distributed.

RESULTS

Comparison of distal-most sites deviations based on bolt alignment

Table 1 presents the median, interquartile range, and minimum-maximum range of the deviations at the distal-most sites of the guides. The two distal-most sites were the maxillary right first molar (MxRFM) for the Group L and the maxillary right canine (MxRC) for the Group S. When aligned on the bolt, the median deviations (mm) at the distal-most sites for Group L and S were 0.889 and 0.283, respectively. Mann-Whitney U testing indicated a statistically significant difference between long and short groups ($P < .001$).

Table 1. Deviations (mm) at distal-most sites based on bolt alignment

Description	Median (mm)	Interquartile Range (Q1, Q3)	Range (Minimum, Maximum)
MxRFM of Group L	0.889	(0.696, 1.020)	(0.326, 1.350)
MxRC of Group S	0.283	(0.186, 0.327)	(0.159, 0.369)

* Absolute values were recorded for negative deviations

Comparison of MxRC deviations based on bolt alignment

Table 2 presents the median, interquartile range, and minimum-maximum range of the deviations at the maxillary right canine (MxRC) sites of the guides. When aligned on the bolt, the median deviations (mm) at the MxRC sites for long and short guides were 0.302 and 0.283, respectively.

Mann-Whitney U testing indicated the values between long and short groups were not statistically different (P = 0.631).

Table 2. Deviations (mm) at MxRC based on bolt alignment

Description	Median (mm)	Interquartile Range (Q1, Q3)	Range (Minimum, Maximum)
MxRC of Group L	0.302	(0.218, 0.361)	(0.165, 0.512)
MxRC of Group S	0.283	(0.186, 0.327)	(0.159, 0.369)

Comparison of bolt angle deviations based on cusp alignment

Table 3 presents the median, interquartile range, and minimum-maximum range of the deviations of bolt angle of the guides when aligned on the cusps. The median deviations (degrees) of the bolt angle for long and short guides were 1.086 and 0.415, respectively. Mann-Whitney U testing indicated a statistically significant difference between long and short groups (P < .001). Deviations of the bolt angle were toward the palatal direction.

Table 3. Deviations of bolt angle (degrees) based on cusp alignment

Description	Median (degrees)	Interquartile Range (Q1, Q3)	Range (Minimum, Maximum)
Group L	1.086	(0.940, 1.284)	(0.539, 1.545)
Group S	0.415	(0.312, 0.627)	(0.219, 0.744)

Comparison of apical point of bolt deviations (mm) based on cusp alignment

Table 4 presents the median, interquartile range, and minimum-maximum range of the deviations of the apical point of the bolt when aligned on the cusps. The median deviations (mm) of the apical point of the bolt for long and short guides were 0.201 and 0.089, respectively. Mann-Whitney U testing indicated a statistically significant difference between long and short groups ($P < .001$). Deviations of the apical point were toward the palatal direction.

Table 4. Deviations of apical point distance (mm) based on cusp alignment

Description	Median (mm)	Interquartile Range (Q1, Q3)	Range (Minimum, Maximum)
Group L	0.201	(0.168, 0.293)	(0.1179, 0.445)
Group S	0.089	(0.048, 0.130)	(0.037, 0.151)

DISCUSSION

The effect of two different spans of 3D printed surgical guide on the distortion by autoclave sterilization was investigated. There were significant differences of dimensional stability of the distal-most sites between the two groups. In addition, the group L demonstrated significantly higher distortion values in terms of angle of bolt and apical direction evaluation. Therefore, the null hypothesis that no significant differences would be found between the two groups after autoclave sterilization was rejected.

Two alignment methods were used in this study to compare samples' pre-sterilization and post-sterilization scans. The first method of alignment was by local best fit on the metal bolt. This is important because the bolt is assumed to be immutable (dimensionally stable) throughout the study. Therefore, making an alignment by selecting only the bolt should reveal the distortion of the resin. The image in the left side of Figure 3 illustrates how the bolt and anterior aspect of the resin guide are well aligned with no deviations (green), and the distal extensions of the resin exhibit considerable deviations in the apical direction (red). The general pattern observed for both groups was that of increasing distortion as the length of the guides increased. Table 1 compares the extent of the distortion at the distal-most sites of the guides for both groups. The longer guides (Group L) suffered significantly greater deviations than the shorter guides (Group S). The maximum deviation recorded was 1.350 mm, which was similar in magnitude to deviations found by Shaheen et al, who recorded 1.5 - 1.7 mm differences at the distal-most aspects of their orthognathic splints.[12]

There are potential clinically relevant consequences for the pattern of distortion. Practitioners commonly evaluate surgical guides by placing them in the mouth and assessing how well they seat on the teeth and how stable they fit without rocking. With this pattern of distortion where the distal extensions are raised apically, the guide would fit like a tripod with contact at the two distal ends and at the center of the anterior. In this scenario, the guide would rest securely on the teeth but would have rotated due to the apical deviation at the distal ends. The distortion could go unnoticed due to the apparently stable fit. If the opposite were true, where the distal ends deviated toward the coronal direction, the guide would rock in the anteroposterior dimension. Consequently, it would be expected that the rotation of the guide due to its raised distal ends would cause the apex of the bolt to rotate toward the palatal. This is what was observed when the guides were aligned by the second method in the present study.

The second method of alignment in the present study was by local best fit on the cuspal regions of the resin. This alignment reveals how the distortion in the resin affects the orientation of the bolt and can be observed in the image to the right side of Figure 3. The band of green along the cuspal regions demonstrate how the scans were aligned. In this alignment, the bolt is no longer green. The facial aspect of the bolt is blue which indicates a negative deviation, and the palatal aspect of the bolt is red which indicates a positive deviation. Therefore, the apex of the bolt has rotated toward the palatal direction. This can also be seen in Figure 4 with the difference in orientation of the virtual cylinders that were constructed on the before (blue) and after (green) scans of the bolt. The median bolt angle deviations (degrees) were significantly different between Group L and Group S. This is to be expected given that the distal extensions of Group L exhibit greater deviations and therefore cause more rotation of the body of the guides.

It is worth noting that no significant differences were found between the groups at the canine sites when the guides were aligned on the bolt. This indicates that most of the distortion took place primarily distal to the canines, as is illustrated in the left side of Figure 3. The results in this study consistently found that shorter surgical guides exhibited less distortion than longer ones. This is logical given that small deviations can accumulate over greater distances. Currently, there is no consensus in literature regarding design elements of surgical guides. More studies would be needed to further investigate the nature of guide resin distortion. Then perhaps better guidelines could be established. Many design factors could potentially affect the stability of the guide during post-processing and sterilization, such as thickness, height, width, length, number of implant sites, and the presence or absence of cross bracing. Other factors such as resin type, printer type, print orientation, and print resolution could also have effects on the properties of the guides.[1,3,5,8,10] Additionally, further investigation would be required to determine what degrees of distortion should be considered clinically relevant.

There were some limitations that could have affected the outcomes of the present study. The surgical guide resin and the metal bolt have surfaces that are not well suited for scanning. The guide resin is translucent and the metal bolt is shiny and reflective. The scanner could not achieve a successful scan without the use of Scanspray. Additionally, the bolts used in this study had a similar diameter as clinically used guide sleeves; however, the bolts had more mass and could have acted as cantilevers, which was not clinically accurate. The bolt could potentially transfer heat or weight into the guides to contribute their own distorting effects. The software inspections did not indicate any distortion around the base of the bolt where it joined the resin guide. The guides could have been placed in a different orientation during sterilization to help identify if the bolts were contributing to the observed distortion pattern. Clinicians should consider these findings on a case-by-case basis. The tolerable degrees of inaccuracy depend on numerous factors such as tooth position, available bone, adjacent structures, and operator experience. If placing multiple implants in the same arch, the clinician could consider whether using multiple shorter guides would improve accuracy over one longer guide.

CONCLUSIONS

Within the limitations of this study, the following conclusions were made:

1. There were significant differences of distortion at the distal-most sites between group L and group S. However, there was no significant difference of distortion up to canine area for both groups. Increasing distortion can be expected as the length of the guide increases.
2. Group L demonstrated significant angular distortion of the implant drill guide tube and significant apical location distortion in comparison with group S.

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APPENDIX A

Data Tables

Table A-1. Short guide results aligned on bolt

ID	MxRC (mm)	MxLC (mm)	Cylinder Length (mm)	Bolt Angle (degrees)	Point Distance (mm)
short-01	0.2673	0.1918	14.9843	0.0000	0.0000
short-02	0.1872	0.1088	15.5176	0.0000	0.0000
short-03	0.1833	0.0696	15.6909	0.0000	0.0000
short-04	0.3143	0.0939	14.8025	0.0000	0.0000
short-05	0.3690	0.1079	16.4818	0.0000	0.0000
short-06	0.3007	0.1028	15.1103	0.0000	0.0000
short-07	0.2872	0.1433	15.4319	0.0000	0.0000
short-08	0.3639	0.2889	15.9322	0.0000	0.0000
short-09	0.1591	0.0887	14.9382	0.0000	0.0000
short-10	0.2786	0.1235	14.9177	0.0000	0.0000
Median (Q1, Q3)	0.2829 (0.1862, 0.3267)	0.1084 (0.0926, 0.1554)	15.2711 (14.933, 15.7512)	0.0000 (0.0000, 0.0000)	0.0000 (0.0000, 0.0000)

Table A-2. Short guide results aligned on cusps

ID	MxRC (mm)	MxLC (mm)	Cylinder Length (mm)	Bolt Angle (degrees)	Point Distance (mm)
short-01	0.0729	0.0616	14.9843	0.5251	0.0371
short-02	0.0761	0.0708	15.5176	0.2193	0.0510
short-03	0.0880	0.0520	15.6909	0.4082	0.0757
short-04	0.0826	0.1043	14.8025	0.6213	0.1184
short-05	0.0962	0.1521	16.4818	0.6432	0.1507
short-06	0.1060	0.0830	15.1103	0.4214	0.0662
short-07	0.0732	0.0754	15.4319	0.3411	0.1294
short-08	0.0895	0.1032	15.9322	0.3342	0.1334
short-09	0.0754	0.0809	14.9382	0.2445	0.0400
short-10	0.0690	0.0854	14.9177	0.7437	0.1015
Median (Q1, Q3)	0.0794 (0.0731, 0.0912)	0.0820 (0.0685, 0.1035)	15.2711 (14.933, 15.7512)	0.4148 (0.3118, 0.6268)	0.0886 (0.0483, 0.1304)

Table A-3. Long guide results aligned on bolt

ID	MxRFM (mm)	MxRC (mm)	MxLC (mm)	MxLFM (mm)	Cylinder Length (mm)	Bolt Angle (degrees)	Point Distance (mm)
long-01	0.8272	0.2319	0.1853	0.7468	14.6709	0.0000	0.0000
long-02	1.0397	0.2156	0.1114	0.6661	15.2505	0.0000	0.0000
long-03	0.6998	0.2183	0.0957	0.5884	14.6739	0.0000	0.0000
long-04	0.3260	0.1645	0.1454	0.4750	15.7276	0.0000	0.0000
long-05	1.0140	0.3520	0.1205	0.7203	15.9245	0.0000	0.0000
long-06	0.6834	0.2569	0.1212	0.6438	15.9926	0.0000	0.0000
long-07	0.8522	0.3462	0.0988	0.6714	15.1172	0.0000	0.0000
long-08	0.9659	0.3886	0.0878	0.6685	15.4571	0.0000	0.0000
long-09	1.3495	0.5120	0.1074	0.7365	17.0884	0.0000	0.0000
long-10	0.9259	0.3481	0.1575	0.8087	14.3184	0.0000	0.0000
Median (Q1, Q3)	0.8891 (0.6957, 1.0204)	0.3016 (0.2176, 0.3612)	0.1160 (0.0980, 0.1484)	0.6700 (0.6300, 0.7391)	15.3538 (14.6732, 15.9415)	0.0000 (0.0000, 0.0000)	0.0000 (0.0000, 0.0000)

Table A-4. Long guide results aligned on cusps

ID	MxRFM (mm)	MxRC (mm)	MxLC (mm)	MxLFM (mm)	Cylinder Length (mm)	Bolt Angle (degrees)	Point Distance (mm)
long-01	0.2222	0.0590	0.0744	0.1940	14.6709	1.0434	0.2191
long-02	0.1880	0.0550	0.1354	0.1554	15.2505	1.4475	0.2959
long-03	0.1140	0.1064	0.0875	0.1492	14.6739	1.0000	0.1179
long-04	0.1649	0.0487	0.0722	0.2116	15.7276	0.5388	0.1829
long-05	0.2484	0.1388	0.0805	0.2322	15.9245	1.2300	0.2914
long-06	0.2294	0.0950	0.0546	0.2270	15.9926	0.7600	0.1781
long-07	0.2076	0.1311	0.0503	0.2118	15.1172	1.0027	0.1720
long-08	0.2486	0.1281	0.0454	0.2511	15.4571	1.1277	0.1546
long-09	0.2747	0.1114	0.0873	0.2455	17.0884	1.5454	0.4448
long-10	0.2406	0.1178	0.0704	0.2722	14.3184	1.1617	0.2757
Median (Q1, Q3)	0.2258 (0.1822, 0.2485)	0.1089 (0.0580, 0.1289)	0.0733 (0.0535, 0.0874)	0.2194 (0.1844, 0.2469)	15.3538 (14.6732, 15.9415)	1.0856 (0.9400, 1.2844)	0.2010 (0.1677, 0.2925)

Table A-5. Comparing long vs short group deviation at canine sites (Mann-Whitney U Test)

Variable	Median (Q1, Q3)	Exact Significance [2*(1-tailed Sig.)]*	Statistical Difference
MxRC aligned on bolt (mm)	0.2829 (0.2163, 0.3510)	0.631	No difference between groups
MxLC aligned on bolt (mm)	0.1101 (0.0965, 0.1449)	0.853	No difference between groups
MxRC aligned on cusps (mm)	0.0888 (0.0730, 0.1102)	0.190	No difference between groups
MxLC aligned on cusps (mm)	0.0780 (0.0638, 0.0875)	0.315	No difference between groups

* Not corrected for ties.

Table A-6. Comparing long vs short group deviation along bolt (Mann-Whitney U Test)

Variable	Median (Q1, Q3)	Exact Significance [2*(1-tailed Sig.)]*	Statistical Difference
Length of cylinder (mm)	15.3412 (14.9228, 15.8753)	0.971	No difference between groups
Bolt Angle aligned on bolt (degrees)	0.0000 (0.0000, 0.0000)	1.000	No difference between groups
Bolt Angle aligned on cusps (degrees)	0.6935 (0.4115, 1.1066)	0.000	Statistical difference between groups
Point Distance aligned on bolt (mm)	0.0000 (0.0000, 0.0000)	1.000	No difference between groups
Point Distance aligned on cusps (mm)	0.1421 (0.0822, 0.2101)	0.000	Statistical difference between groups

* Not corrected for ties.

Table A-7. Descriptive statistics for distal-most sites

Variable	Median (Q1, Q3)
Short guide aligned on bolt (mm)	0.2829 (0.1862, 0.3267)
Short guide aligned on cusps (mm)	0.0794 (0.0731, 0.0912)
Long guide aligned on bolt (mm)	0.8891 (0.6957, 1.0204)
Long guide aligned on cusps (mm)	0.2258 (0.1822, 0.2485)

Table A-8. Comparing long vs short group deviation at distal-most sites (Mann-Whitney U Test)

Variable	Median (Q1, Q3)	Exact Significance [2*(1-tailed Sig.)]*	Statistical Difference
Distal-most Site aligned on bolt (mm)	0.3665 (0.2808, 0.9075)	0.000	Statistical difference between groups
Distal-most Site aligned on cusps (mm)	0.1100 (0.0778, 0.2276)	0.000	Statistical difference between groups

* Not corrected for ties.