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# Impact of an intraoral X-ray cone with positioning laser lights on reducing radiographic errors with the bisecting angle technique: A technical report

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## ABSTRACT

**Purpose**: The bisecting angle technique (BAT) encounters difficulties in positioning the X-ray cone and aligning the central beam with the tooth. To address this, a rectangular laser featuring a pointed light was integrated into the intraoral X-ray cone. This study evaluated its effectiveness in improving radiograph quality and minimizing errors.
**Materials and Methods**: Fifty fifth-year Bachelor of Dental Surgery students were divided into 3 groups. Group 1 (n = 16) used the paralleling technique, group 2 (n = 17) employed the conventional BAT, and group 3 (n = 17) utilized the laser-assisted BAT on mannequins. Two independent oral radiologists assessed the quality of the radiographs, categorizing the images as either diagnostically acceptable or not acceptable. Inter-group comparisons of quality and error rates were conducted using the chi-square test (significance level: $P < 0.05$).
**Results**: The paralleling technique group produced 77.5% diagnostically acceptable radiographs and 22.5% that were not diagnostically acceptable. These percentages were 65.3% and 34.7%, respectively, in the conventional BAT group and 75.3% and 24.7%, respectively, in the laser-assisted BAT group, showing results similar to the paralleling technique group. The quality of radiographs differed significantly among the groups ($P < 0.05$). The percentage of error-free radiographs was 38.1% in the paralleling technique group, 20.6% in the conventional BAT group, and 40.0% in the laser-assisted BAT group, with these differences being statistically significant ($P < 0.05$).
**Conclusion**: The device produced higher acceptability and fewer radiographic errors than the conventional BAT technique, suggesting accurate adjustment of the X-ray cone and central beam to the desired teeth. ***(Imaging Sci Dent 2025; 55: 65-71)***

**KEY WORDS**: Dental Radiography; Lasers; Technique, X-rays

## Introduction

Intraoral periapical radiographs play a crucial role in clinical dentistry, aiding both diagnosis and treatment planning.[1,2] These radiographs are commonly obtained using the paralleling technique and the bisecting angle technique (BAT). The paralleling technique is generally preferred due to its standardization, reproducibility, and minimal image distortion, making it a common choice in clinical practice.[3,4] Nonetheless, the paralleling technique has limitations, such as challenges in achieving parallelism between the tooth and the image receptor, particularly in patients with anatomical variations such as shallow palates or tori. Additionally, placing the receptor in the posterior regions, especially near the third molars, may cause discomfort. In such cases,

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the BAT is often chosen due to its simpler film positioning and greater patient comfort.[4]

The BAT uses the isometry principle, which asserts that 2 triangles are congruent if they have 2 equal angles and a shared side. In this technique, the X-ray receptor is positioned on the lingual surface of the tooth, angled relative to its long axis. An imaginary bisector then splits this angle, and the central ray is directed perpendicularly to it. This setup forms 2 congruent triangles, thereby ensuring an accurate representation of the tooth's length.[4-6]

Researchers assert that diagnostically acceptable radiographs can be achieved using the BAT with precise X-ray cone positioning and accurate adjustment of angulation and central beam alignment to anatomical landmarks.[1,2,4] While the BAT is advantageous in cases with anatomical constraints, its complexity arises from the need to align the central X-ray beam to the theoretical bisector without the aid of an aiming ring. Additionally, directing the beam's entry point to facial landmarks with precise vertical and horizontal angulation presents considerable challenges.[3,4]

Improper adjustment of the X-ray cone and inaccurate positioning of the central X-ray beam can lead to errors such as cone cuts, elongation, foreshortening, and tooth overlap. These errors often necessitate repeat radiographs, exposing patients to additional radiation.[7,8] Innovative radiographic techniques and tools are essential in addressing the inherent limitations of the BAT. Numerous researchers have proposed modified BAT approaches to enhance image precision, especially in the maxillary molar region, to prevent zygomatic superimposition and periapical cut-off. These adaptations produce images as accurate as those obtained with the paralleling technique.[9-11] Azizah et al.,[12] Chau et al.,[13] and Al-Safi et al.,[14] have investigated the use of external markers, laser lights, and precise anatomical landmark identification, respectively, to improve accuracy and reduce radiographic errors.

However, the challenge of precisely aligning the X-ray beam's entry point with facial landmarks is crucial for accurately capturing anatomical structures and minimizing errors, yet this issue remains inadequately addressed. Therefore, this study attempted to design a rectangular-shaped laser device, roughly the size of an intraoral X-ray film. This device was intended to outline the film's position within the oral cavity before exposure. Additionally, a centrally focused pointed laser beam was incorporated into the X-ray cone to guide the X-ray's entry point onto facial landmarks for the BAT. This technical report aimed to evaluate the effectiveness of this device in producing high-quality radiographs and reducing radiographic errors, compared to the conventional BAT and the paralleling technique.

## Materials and Methods

Fifty Bachelor of Dental Surgery year five students were divided into 3 groups. Group 1, employing the paralleling technique, comprised 16 participants. Groups 2 and 3 each had 17 participants and used the conventional BAT and the laser-assisted BAT, respectively. Prior to the study, participants in Groups 1 and 2 independently reviewed the BAT technique. Meanwhile, Group 3 received a practical demonstration on how to use laser lights to align the central X-ray beam with the target area. This involved using the pointed laser light to identify the entry point based on extraoral anatomical landmarks on a mannequin (Rinn Dentsply, DXTTR III 54-6002, Elgin, USA).

Each student performed intraoral periapical radiographs on the maxillary and mandibular right central incisors, canines, first premolars, and first molars of the mannequin. These specific teeth were chosen due to the required vertical angulations and precise X-ray beam entry points, which were guided by established extraoral anatomical landmarks as detailed in Table 1.[1,4] In total, each student took 8 radiographs with the mannequin.

The radiographs were taken using a Rinn Snap-A-Ray film holder (Dentsply Sirona, Charlotte, USA). For the imaging, size 1 and size 2 photostimulable phosphor recep-

**Table 1.** Vertical angulations for maxillary and mandibular teeth and point of entry of the central X-ray beam

| Teeth | Maxilla | | Mandible | |
|---|---|---|---|---|
| | Vertical angulation | Point of entry | Vertical angulation | Point of entry |
| Incisors | +40 | Tip of the nose | −15 | Tip of the chin |
| Canines | +45 | Ala of the nose | −20 | Corner of the mouth |
| Premolars | +30 | Intersection of the mid-pupillary line and ala tragal line | −10 | Intersection of the mid-pupillary line and oro-tragal line |
| Molars | +20 | Intersection of the Lateral canthus of the eye and the ala tragal line | −5 | Intersection of the lateral canthus of the eye and oro-tragal line |

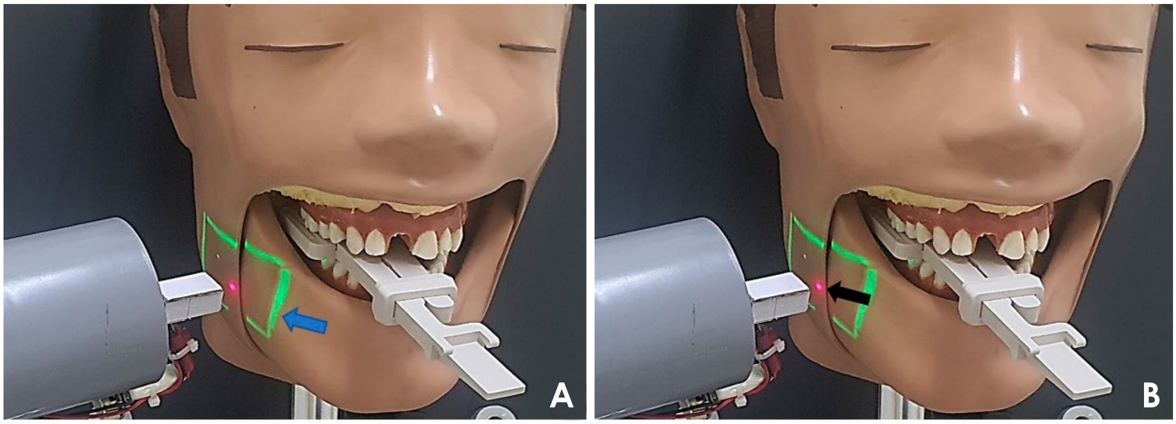


**Fig. 1.** The X-ray cone is fitted with positioning laser lights. A. The blue arrow highlights the green rectangular laser beams, which align with the dimensions of an intraoral film. B. The black arrow indicates the central red laser light positioned at the center of the X-ray cone, marking the entry point of the central X-ray beam.

**Table 2.** Subjective image quality ratings and basis for dental radiographs outlined by the Faculty of General Dental Practice (UK)

| Quality rating | Basis | Target | |
|---|---|---|---|
| | | Digital imaging | Film imaging |
| Diagnostically acceptable | No errors or minimal errors in either patient preparation, exposure, positioning, image (receptor) processing or image reconstruction and of sufficient image quality to answer the clinical question | Not less than 95% | Not less than 90% |
| Diagnostically not acceptable | Errors in either patient preparation, exposure, positioning, image (receptor) processing or image reconstruction which render the image diagnostically unacceptable | Not greater than 5% | Not greater than 10% |

tors (Apixia Digital Dental Imaging, Taipei, Taiwan) were employed for anterior and posterior teeth, respectively. These were scanned using a phosphor plate scanner (Apixia DIGIREX PSP Scanner, AC 100-240 V, scan time: 10 s, resolution: 17 lp/mm). A Belmont Phot-X2303-WK wall-mounted X-ray unit (Belmont Equipment, Division of Takara Belmont, USA) with a rectangular collimator was utilized, with exposure settings consistently maintained at 70 kVp, 7 mA, and 0.12 s.

### Fabrication of positioning indicating lights

A low-power green laser diode (VLM-520028-LPT, Quarton Inc, Taipei, Taiwan), emitting a line laser light with an output of less than 1 mW, was mounted on the inner surface of the X-ray machine near the outer edge of the collimator and at the base of the X-ray cone. Four such green laser diodes were installed, creating a rectangular light pattern that matched the dimensions of an intraoral film (Fig. 1A). Additionally, a low-power red laser diode (VLM-520028-LPT, Quarton Inc, Taipei, Taiwan), which emits a pointed beam with a maximum output of 1 mW, was precisely positioned at the center of the open-ended cylindrical X-ray cone (Fig. 1B). All laser diodes were powered by lithium batteries and controlled by a switch located on the side of the X-ray cone. The orientation of the red pointed laser was adjustable; it was mounted on the outer surface of the cone using an extended plastic rod, which allowed for lateral adjustments from the cone's central position just before X-ray exposure. The cone could be rotated vertically for imaging anterior teeth and horizontally for posterior teeth.

The radiographs were evaluated using a 2-point quality rating scale developed by the Faculty of General Dental Practice UK, which classified them as either "diagnostically acceptable" or "not acceptable." Table 2 outlines the criteria for subjective image quality ratings of dental radiographs.[15] The initial edition of this guidance advocated a 3-point scale for the subjective quality rating of dental radiographs, categorizing them as excellent, acceptable, or unacceptable. In the subsequent edition, this was substituted with a 2-point rating scale and included performance targets that represent achievable standards in most well-managed dental practices.[15,16]

The evaluation was conducted by 2 oral radiologists, each with more than 10 years of experience, who did not participate in data collection and were blinded to the study groups. The images were examined on a monitor in a reporting room under semi-dark lighting conditions. Inter-examiner reliability was assessed using the kappa index, which yielded a value of 0.854, indicating near-perfect agreement between the examiners.

Differences in radiographic quality and error types were evaluated using the chi-square test. Inter-rater agreement and group differences were analyzed with kappa statistics and the Mann-Whitney U test. A significance level of $P<0.05$ was applied. All statistical analyses were performed using the SPSS version 28.0 (IBM Corporation, Armonk, NY, USA).

## Results

Given the perfect agreement between the 2 examiners, subsequent analyses were conducted using data from only 1 examiner. Group 1 captured a total of 160 radiographs, whereas Groups 2 and 3 each captured 170 radiographs.

An inter-group comparison of radiograph quality (Table 3) showed that participants using the paralleling technique produced the highest percentage of diagnostically acceptable radiographs (77.5%) and the lowest percentage of diagnostically unacceptable radiographs (22.5%). Conversely, students employing the conventional BAT achieved a lower rate of diagnostically acceptable radiographs (65.3%) and a higher rate of diagnostically unacceptable radiographs (34.7%). Group 3, which used the laser-assisted BAT, had percentages of diagnostically acceptable (75.3%) and unacceptable radiographs (24.7%) that were similar to those of group 1. The chi-square test indicated a significant difference in radiograph quality among the groups ($P>0.05$), suggesting that both the paralleling technique and the laser-assisted BAT are more effective at producing diagnostically acceptable radiographs than the conventional BAT. An inter-group comparison of radiographic error types (Table 4) showed that the paralleling technique group had a relatively high percentage of error-free radiographs (38.1%) and the lowest incidence of common errors such as cone cut (13.8%) and overlapping (20.0%). Other radiographic errors observed included foreshortening (5.0%), elongation (9.4%), and film positioning errors (13.8%). In contrast, the conventional BAT group exhibited the lowest percentage of error-free radiographs (20.6%) and higher rates of common errors like cone cut (18.8%) and overlapping (21.8%), along with foreshortening (12.4%), elongation (14.1%), and film positioning errors (12.4%). The laser-assisted BAT group demonstrated the highest percentage of error-free radiographs (40.0%) and lower rates of cone cut (14.7%), overlapping (18.2%), foreshortening (6.5%), elongation (9.4%), and film positioning errors (11.2%). Statistical analysis using the chi-square test indicated a significant difference in the types of errors among the groups ($P>0.05$), suggesting that the paralleling tech-

**Table 3.** Inter-group comparison of radiograph quality (chi-square test)

| Group | Diagnostically acceptable n (%) | Diagnostically not acceptable n (%) | *P*-value |
|---|---|---|---|
| Paralleling technique (160 radiographs) | 124 (77.5%) | 36 (22.5%) | |
| Conventional bisecting angle technique (170 radiographs) | 111 (65.3%) | 59 (34.7%) | <0.05 |
| Laser-assisted bisecting angle technique (170 radiographs) | 128 (75.3%) | 42 (24.7%) | |

**Table 4.** Inter-group comparison of types of radiographic errors (chi-square test)

| Group | No error | Cone cut | Over lapping | Fore shortened | Elongation | Film positioning | *P*-value |
|---|---|---|---|---|---|---|---|
| Paralleling technique (160 radiographs) | 61 (38.1%) | 22 (13.8%) | 32 (20.0%) | 8 (5.0%) | 15 (9.4%) | 22 (13.8%) | |
| Conventional bisecting angle technique (170 radiographs) | 35 (20.6%) | 32 (18.8%) | 37 (12.4%) | 21 (12.4%) | 24 (14.1%) | 21 (12.4%) | <0.05 |
| Laser-assisted bisecting angle technique (170 radiographs) | 68 (40.0%) | 25 (14.7%) | 31 (18.2%) | 11 (6.5%) | 16 (9.4%) | 19 (11.2%) | |

**Table 5.** Inter-rater agreement and differences among groups

| | | Paralleling technique | Conventional bisecting angle technique | Laser-assisted bisecting angle technique |
|---|---|---|---|---|
| Inter-rater agreement among groups | kappa | .521 | .673 | .765 |
| | *P*-value | $<0.05$ | $<0.05$ | $<0.05$ |
| Inter-rater difference among groups | Z | $-.133$ | $-.897$ | $-.125$ |
| | *P*-value | .894 | .370 | .900 |

nique and laser-assisted BAT are more effective in minimizing errors compared to the conventional BAT.

Table 5 presents the inter-rater agreement and differences for the 3 groups. The group using the paralleling technique showed moderate agreement, with a kappa value of 0.521 ($P<0.05$). The conventional BAT group achieved substantial agreement, indicated by a kappa value of 0.673 ($P<0.05$). The laser-assisted BAT group exhibited the highest level of agreement, with a kappa value of 0.765, suggesting substantial to almost perfect agreement ($P<0.05$). Inter-rater differences among the groups were also analyzed. The paralleling technique group had a Z-value of $-0.133$ ($P>0.05$), the conventional BAT group had a Z-value of $-0.897$ ($P>0.05$), and the laser-assisted BAT group had a Z-value of $-0.125$ ($P>0.05$). According to the Mann-Whitney U Test, these differences were not statistically significant ($P<0.05$).

## Discussion

The BAT presents considerable challenges in clinical settings, especially when dealing with anatomical variations such as shallow palates, tori, and difficulties with bite blocks.[1,17,18] Despite its advantages, the BAT is associated with higher radiographic errors due to the need for precise X-ray cone alignment. Mastery of technique and accurate use of radiographic accessories are essential for obtaining high-quality radiographs. Advanced teaching tools, such as positioning lights, can help reduce errors, improve radiographic quality, and decrease retake rates.

The laser-assisted BAT group achieved a high percentage of diagnostically acceptable radiographs (75.3%) and a low rate of diagnostically unacceptable radiographs (24.7%), comparable to the paralleling technique group. This underscores the participants' ability to accurately position the X-ray cone without an aiming ring. In contrast, the conventional BAT group produced a lower percentage of acceptable radiographs (65.3%) and a higher rate of unacceptable ones (34.7%). This indicates poor diagnostic quality and suggests a potential need for retakes. Notably, this unacceptable rate surpasses the average rejection rate of 16.4% reported for periapical radiography in a recent systematic review.[7]

Previous studies have documented the use of repeat radiographs with the conventional BAT in clinical settings. However, the findings of the present study are more aligned with those studies that have modified intraoral techniques to minimize error rates. Azizah et al.[12] employed an external facial marker for cone placement, reducing errors to 31%. Chau et al.[13] integrated a laser-guided rectangular collimator on the X-ray cone, achieving a 16% repetition rate in their laser group for both the bitewing and paralleling techniques. Unlike these methods, the present study exclusively used laser positioning lights for the BAT, which do not rely on an aiming ring for cone adjustment. The rectangular laser collimators adopted by Chau et al.[13] have limited utility in the paralleling technique, where aiming rings assist in cone positioning, while BAT holders lack such aids, making precise X-ray beam alignment a challenge for students and clinicians.

The percentage of unacceptable radiographs significantly decreased with the laser-assisted BAT (24.7%) compared to the conventional BAT, although it still exceeded the threshold set by the Faculty of General Dental Practice UK.[15] However, this rate was lower than the 48.6% reported by Kazzi et al.[19] The improved performance of the laser-assisted BAT is likely due to the laser positioning lights on the X-ray cone, which enabled participants to adjust the cone accurately, resulting in more diagnostically acceptable radiographs. Nonetheless, further reducing the repetition rate is critically important, given the high volume of intraoral radiographs in clinical practice. Minimizing retakes not only lowers radiation exposure for patients, clinicians, and radiology staff, but also saves valuable time and resources.[20]

Significant error reductions were observed in the laser-assisted BAT group, especially with cone cuts (14.7%) and overlapping errors (18.2%) compared to the conventional BAT group. Similar findings were reported by Azizah et al.[12] and Chau et al.,[13] who used an external marker for aiming and a laser collimator, respectively, with cone cuts identified as prevalent errors. Shetty et al. developed a laser-guided apparatus named the Laxmi-Kanth Aiming Device, which can be capped to the X-ray machine to precisely identify extraoral landmarks. They suggested that implementing this apparatus could significantly reduce technical errors among dental students.[21]

Current literature indicates that cone cuts and elongation are the most common radiographic errors, while image blurring is the least frequent.[8] The laser-assisted BAT group exhibited fewer errors compared to both the conventional BAT and the paralleling technique. However, the proportion of diagnostically acceptable radiographs did not meet the benchmark set by the recent 2-point rating scale.[15] To improve performance, a deeper understanding of the technique is essential. This can be achieved through the use of virtual reality tools, innovative teaching aids, and repetitive practice during preclinical and clinical training. Inter-rater agreement was assessed using Kappa statistics. There was moderate agreement in the paralleling technique group, in contrast to the higher kappa value observed in the conventional BAT group. This discrepancy is likely due to the clearer guidelines provided by the Faculty of General Dental Practice UK, which classify radiographs as either "diagnostically acceptable" or "diagnostically not acceptable," as opposed to the earlier 3-point scale. Furthermore, inter-examiner calibration involving 25 radiographs prior to the study likely enhanced rater consistency, reflecting increased familiarity among the assessors.

In this technical report, the authors developed and evaluated the use of positioning laser lights for cone adjustment and central X-ray beam alignment using a mannequin in a controlled preclinical setting. Consequently, these findings cannot be extrapolated to real patients. Additionally, the small group of participants conducted a limited number of radiographs after brief training. Further research involving a larger sample of actual patients and more experienced radiology technicians is essential to comprehensively assess the device's effectiveness and usability.

The laser positioning lights were designed for X-ray machines with a round cone, limiting their use with rectangular cones. Another challenge is compatibility with various intraoral X-ray machines due to differences in cone shapes and specifications, potentially requiring custom adjustments. Furthermore, the current laser device requires a separate circuit and must be positionally adjusted prior to X-ray exposure. Integrating the device directly into the cone, while ensuring it does not interfere with the X-ray beam and operates on a unified circuit, could simplify the setup process and eliminate the need for repeated adjustments. This integration would also enable the X-ray cone to be positioned closer to the patient's skin. However, it remains challenging to position the laser in a way that does not disrupt the central X-ray beam. Alternative approaches could involve moving the X-ray cone closer to the skin after repositioning the laser lights to the edge of the cone without changing the angulation. Another option might be to develop a shorter, centrally pointed laser light that could be positioned at the tip of the cone.

In conclusion, attaching positioning laser lights to the X-ray cone aided in aligning the cone to the region of interest. This straightforward but highly effective tool enabled participants to capture diagnostically acceptable intraoral radiographs with minimal repetition and significantly reduced the common radiographic errors often associated with the conventional BAT.

**Conflicts of Interest:** None

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