COMPARATIVE EVALUATION OF FACTORS MINIMIZING THE AMOUNT OF NEEDLE DEFLECTION DURING INFERIOR ALVEOLAR NERVE BLOCK – AN IN VITRO STUDY

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Abstract

Failure of local anaesthesia is a common problem faced in the clinical practice. Inferior alveolar nerve block is showing high percentage of failure among the local anaesthesia techniques. The study is conducted to understand the factors minimising the amount of needle deflection during the inferior alveolar nerve block.

Successful local anaesthesia has been critical to the daily practice of dentistry. It is required to ensure maximum patient comfort while clinical procedures are being performed. The main objective of the study is to assess various factors affecting the deflection of the needle while giving inferior alveolar nerve block anaesthesia in a tissue like material agar-agar having almost similar physical properties to human tissues.

This study was conducted to investigate the cause-and-effect relationship between many factors (needle gauge, tip design, angle of insertion, insertion technique and thickness of tissue) and amount of needle deflection during inferior alveolar nerve block.

The study was conducted with fourteen in vitro deflection test models (2.5x2x2 cm) using tissue like substance (reversible hydrocolloid) mounted on a dental surveyor for standardized needle insertions to standardized depth of 25 mm and radiographic analysis was performed after each insertion by measuring the vertical deflection in millimetres (to the nearest 1/10th mm). We used the one-way ANOVA procedure with multiple comparisons.

The present study indicates that tip of needle design, technique of insertion and thickness of tissue can significantly affect the deflection of the needle while factor like angle of insertion of the needle has the least effect on amount of deflection.

The present report indicates that thickness of the tissue and gauge of needle has significant effect on the amount of needle deflection. At the same time, bi-bevelled needle tip and rotational insertion technique provide minimum amount of deflection. Angle of insertion has the least effect on amount of deflection.

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Introduction

An injection that is recognized as one of the most difficult in dentistry is the inferior alveolar nerve block [1] .The main areas that are anesthetized are the body of the mandible, and the inferior portion of the ramus of the mandible, mandibular teeth, mucous membrane and the underlying tissues that is anterior to the 1st molar tooth.

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Anatomical landmarks that you have to remember -

1. Mucobuccal fold
2. Anterior border of the ramus of the mandible
3. External oblique ridge
4. Retromolar triangle
5. Internal oblique ridge
6. Pterygomandibular ligament

7. Buccal sucking pad
8. Pterygomandibular space

A number of factors can be associated with the failure of attaining good anaesthesia including anatomic variations , operator technique and needle deflection [2]. The inferior alveolar nerve is contained within petrygomandibular space. The final target of the needle tip being the mandibular foramen, it must penetrate a variety of tissues , including mucosa , buccinator muscle, sub-mucosal connective tissue , fat and the temporo-pterygoid fascia[3]. All of these tissues will offer varying degrees of resistance to needle penetration[4] and contribute to deflection which is considered as one of the major contributing factors to failure of anaesthesia. Roda[4] reported that failure of inferior block can range from 20% to 30%, and most of dentists have experienced some difficulty with achieving successful anaesthesia.

According to John. 2010[5], the causes of Inferior alveolar nerve block failure are

1. Unable to find a bony landmark with the needle.
2. Unable to direct the needle satisfactorily due to tough tissue in the petrygomandibular space.
3. Awkward tongue, either excessively large or due to lifting posteriorly. Some patients seem unable to allow the tongue to rest passively.
4. Difficult anatomy where posterior teeth have been lost and alveolar resorption has been excessive.
5. Accessory innervations to the mandibular teeth)
6. Improper technique
7. Anatomic variation (retro molar foramen – bifid inferior alveolar nerve -)
8. Inflammation and infection-Local anaesthetic pKa - pH factors and tissue pH factors
9. deflection of needle.
10. Inadequate volume deposition.
11. Jaw size discrepancy and the needle.

Failures in local anaesthesia may result from any of these causes. The most important thing to be ascertained by the operator is to identify the exact cause of the failure. It is well recognised that local anaesthesia readily fails in the presence of acute inflammation. This is commonly due to a pH decrease (to 5 or 6) in inflamed tissue, associated with mediators of inflammation[6] . This theory may explain failure of infiltration anaesthesia but it does not explain failure of nerve blocks where local anaesthetic is deposited away from the site of infection. Hyperaemia during acute inflammation will cause washing of local anaesthetic from the system and increased elimination via diffusion into local blood vessels Hyperalgesia is when the threshold of nociceptive neurones to noxious stimuli is decreased, both in and around the site of insult. Excessive discharge from these nerves results from the weakest of noxious stimuli. This was demonstrated by Rood and Pateromichelakis, who applied artificial inflammation to sciatic nerves in rats.

There was an increased rate of firing and action potential amplitude for the inflamed nerves opposed to the control nerves, suggesting hyperalgesia. Rood concluded that a solution to hyperalgesia is to use a stronger concentrationof drug (5% lignocaine with adrenaline), which will sufficiently block hyperalgesic nerves. The fact that higher concentrations of local anaesthetic agents are more neurotoxic than lower concentrations of the same agent has been conclusively shown in laboratory studies using lignocaine[6]. If the failure is due to anatomical variation, for example in mandibular blocks involving bifid canals, it is advisable to perform higher anaesthetic technique, such as that proposed by Gow-Gate.

Various methods were tried to reduce the percentage of failure in inferior-alveolar nerve block. Arthur[7]used scanning electron micrographs of the non-deflecting and conventional local anaesthetic needle tips .This concomitantly reduces coring area by 75%, thus reducing the amount of tissue captured in the needle lumen as the tip is advanced, as well as contributing to decreased deflection. A special baked-on silicone coating is also used on the non-deflecting needle to reduce drag through tissues. Adam Radford[8] has divided the causes of failure of local anaesthesia under a number of headings. Operator dependent failure is the most common cause of failure of IANB along with mis-localization of mandibular foramen and will result in deposition of solution too near in the medial pterygoid muscle or too far into the parotid gland. Nerve block injections are considered more technically difficult, and somewhat less predictable than infiltration injections. Clinical studies suggest success rates of about 75-90% or more in patients with clinically normal teeth. Studies have shown success rates of only 19-56% for IAN blocks in patients with irreversible pulpitis.[8] Management over this failure can be carried out by reviewing clinician's knowledge of anatomy and clinical injection technique and radiographic assessment for mandibular foramen.

In his study John[5]stressed various causes of Inferior alveolar nerve block failure which include inability to find a bony landmark with the needle and the difficulty to direct the needle satisfactorily through the tough tissue in the petrygomandibular space.Difficult anatomy is often quite challenging where posterior teeth have been lost and alveolar resorption has been excessive and can also result in failure of anaesthesia. Other factors which are found to be responsible are accessory innervations to the mandibular teeth, anatomic variation, retro-molar foramen, bifid inferior alveolar nerve, and local inflammation and infection. Other factors include Local anaesthetic pKa - pH factors and tissue pH factors, deflection of needle and inadequate volume deposition. Failures in local anaesthesia may result from any of these causes. The most important thing to be ascertained by the operator is to identify the exact cause of the failure.

If the failure is due to anatomical variation, for example in mandibular blocks involving bifid canals, it is advisable to perform higher anaesthetic technique, such as that proposed by Gow-Gate. Nigel D Robb, in 2011[10].demonstrated that the Kenneth Reed technique, using a different injection point and target, is equally effective at producing anaesthesia of the inferior alveolar nerve. Compared with conventional techniques there is a lower incidence of positive aspiration and the potential for lower morbidity due to the greater distance between the point of injection of the local anaesthetic and the neurovascular bundle than at the level of the mandibular foramen which is the target for most conventional IANB techniques.

Another technique which is commonly employed is Gow Gates technique which uses both extra and intra oral land marks for minimizing the chances of failure as mandibular occlusal plane is not a reliable guide for identifying the mandibular foramen. Controversy in literature exists regarding the factor responsible for needle deflection [11], and this study was conducted to determine which factor had the greatest influence on needle deflection.

Dental needles are available in 3 lengths: long (32 mm), short (20 mm), and ultrashort (10 mm).Needle gauges range from size 23 to 30.[12]

Recommendations:

1. For the administration of local dental anesthesia, dentists
should select aspirating syringes that meet ADA standards.

2. Short needles may be used for any injection in which the thickness of soft tissue is less than 20 mm.

Any 23- through 30-gauge needle may be used for intraoral injections, since blood can be aspirated through all of them. Aspiration can be more difficult, however, when smaller gauge needles are used. An extra-short, 30-gauge is appropriate for infiltration injections.[13]

3. Needles should not be bent if they are to be inserted into soft tissue to a depth of >5 mm or inserted to their hub for injections to avoid needle breakage. In the majority of cases (70%), needle fracture happened during inferior alveolar nerve block. Kronman et al. showed in their cadaver study in 1994 that the needle has to penetrate about 21 mm deep into the soft tissue to reach the mandibular foramen for adequate anesthesia of the inferior alveolar and lingual nerve]. In looking at the anatomical situation of this area in more detail, Okamoto et al. showed in their radiographic study in 2000 that the best possible anesthetic effect is achieved by inserting the needle between the muscle tendon of the temporalis muscle and the medial pterygoid muscle directly into the petrygomandibular space. However, in the majority of cases, the needle penetrates dense, bulky structures as the medial pterygoid muscle or the tendon of the temporalis muscle.

Therefore, tissue resistance is high in this area, and increases when the mouth is open. During deep penetration of the needle in these tight structures, the risk of needle fracture increases[13]. One important cause for a high percentage of needle fractures is the fact that most dentists (76%) used thin and short needles with a dimension of 30G, which equals to 0.305 mm outer diameter, probably due to the mistaken belief that the thickness of the needle correlates to the degree of pain. But pain perception is individual and is not only dependent on needle size, as was shown in the studies of Fuller et al. and Mollen et al.

Aims and objectives

This study was conducted to investigate the cause-and-effect relationship between many factors and needle deflection during inferior alveolar anaesthesia. The factors studied are

1- Thickness of the tissue and the amount of needle deflection.
2- Design of the tip of the needle on
3- Technique of insertion and the amount of deflection.
4- Gauge of needle and amount of deflection.
5- The angle of insertion and the amount of deflection.

Materials and methods

The aim of the study is to determine whether deflection of needle in tissue like substance could be minimized when using needles of different gauges (gauges 27& 30).We also compared the effect of tissue thickness in causing various degrees of needle deflection, by using three moulds of different height (2.5X3X3.5 cm) ,where the height of mould in our study would represent thickness of tissue clinically.

It was also tried to find out which technique of insertion will have the minimum amount of deflection, using 3 techniques of insertion (linear, rotational, one with bevel away from bone then one full rotation to bring bevel toward the bone) Not only that we have tried to study whether angle of insertion has a value in reduction of needle deflection, by studying 4 different angles of insertion (30 - 35- 40 -45 degrees respectively). Lastly we tried to measure the amount of deflection when using different needle tip design, the conventional needle tip and bi-bevelled needle tip done in university lab and confirmed under microscope. Figure (3)

The present study was conducted in, with reversible hydrocolloid (Agar-agar) which is similar in its actual dielectric properties of human tissues. Based on all previous studies, we selected agar- agar as tissue-like material in our study because of its high similarity to properties of human tissue .The technique used is to measure deflection of the needle was *based on* the technique previously reported by Aldous[15]. Needles obtained from a local dental supply company were mounted in the movable shaft of a dental surveyor, figure (7) under which a block of reversible hydrocolloid in room temperature was placed. The needles were then introduced into the hydrocolloid and pushed into the material to about more than half of needle.

After insertion, radiographs of the hydrocolloid chamber were made, using Rinn extension cone paralleling devices to ensure consistent positioning of the x-ray tube and standardization.

A vertical metal rod held outside the hydrocolloid chamber appeared on the radiographic image and provided a true vertical axis from which needle deflection could be measured.

70 radiographs were taken for all groups (5 radiographs for each sub-group, to calculate the average of deflection after needle insertion) using same parameter used by Dr,Arthur[7], (parameter of 15 mA, 65 Kvp).

Fourteen moulds were prepared in agar agar material and arranged in to 4 groups as follows Sample A : (total of 4 moulds were used), figure (1).

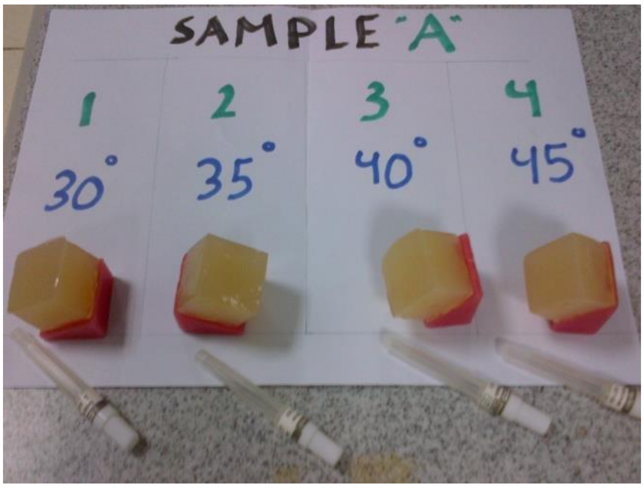

Figure 1. Sample A

A-1 : standard mould with wax base to have surface angle of 30 degree , use conventional long 27 gauge .
A-2 : standard mould with wax base to have surface angle of 35 degree , use conventional long 27 gauge .
A-3 : standard mould with wax base to have surface angle of 40 degree , use conventional long 27 gauge .
A-4 : standard mould with wax base to have surface angle of 45 degree , use conventional long 27 gauge .

Sample B : (total of 4 moulds used), figure (2).

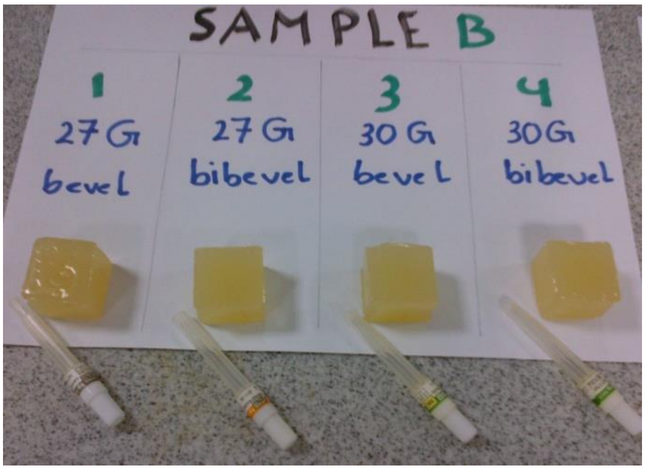

Figure 2. Sample B.

B-1: standard mould with conventional long 27 gauge.
B-2 : standard mould with modified needle tip (bi-beveled tip) long 27 gauge. See figure (3)

Figure 3. Long needle gauge 27 (modified tip), bibevel needle under microscope.

B-3 : standard mould with conventional long 30 gauge .
B-4 : standard mould with modified needle tip (bibevel tip) long 30 gauge.

Sample C : (total of 3 moulds used) , figure (4),(5)
C-1 : standard mould , long 27 gauge , linear insertion technique .
C-2 : standard mould , long 27 gauge , rotational insertion technique .
C-3 : standard mould , long 27 gauge , insert with bevel away from base then after fully insertion , rotate the needle toward the base. figure (4)

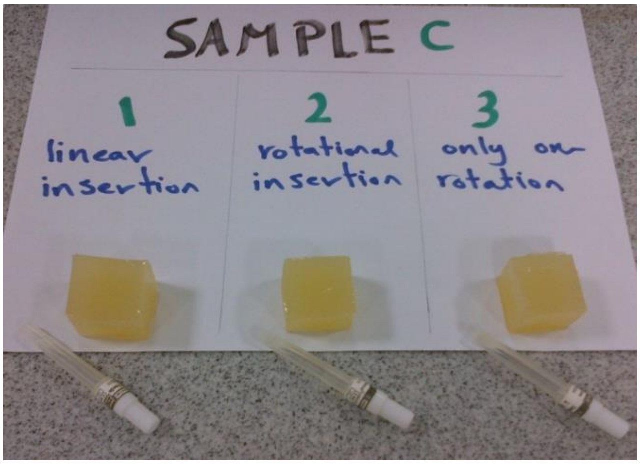

Figure 4. Sample C.

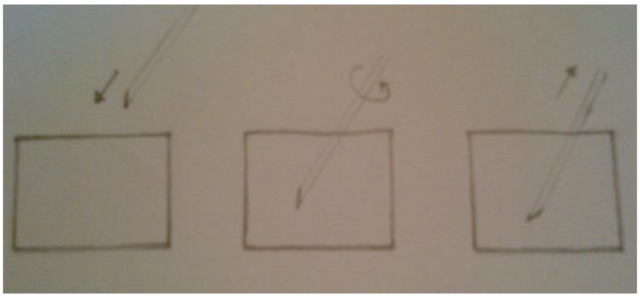

Figure 5. One rotation technique.

Sample D: (total of 3 moulds used)
D-1: standard mould, long 27 gauge .
D-2 : 3 cm height of mould , long 27 gauge.
D-3 : 3.5 cm height of mould , long 27 gauge. Figure (6).

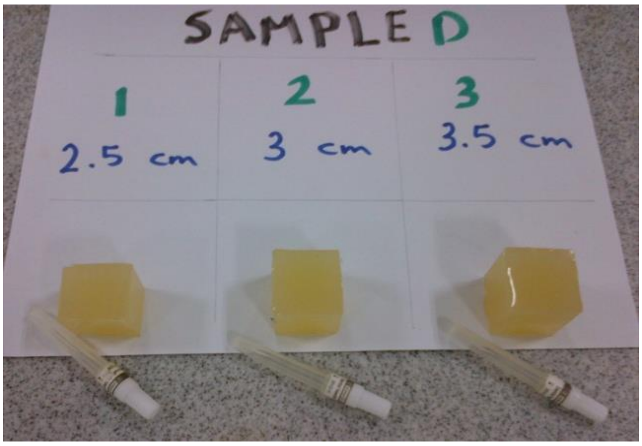

Figure 6. Sample D.

Amount of vertical needle deflection is measured in millimetres (to the nearest 1/10th cm) and we measured from tip of needle to vertical line drawn from first point of needle insertion in the mould. See figure (8).

Figure 7. Standard mold mounted on surveyor with cone parallel device used.

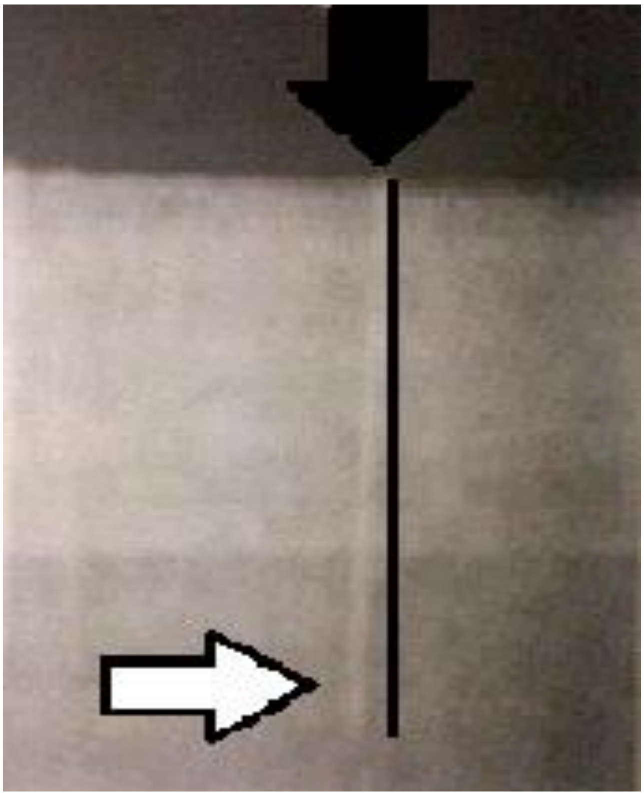

Figure 8. Radiographic analysis of needle deflection.

Results

Deflection values of the needle for each group with some summery statistics are presented in table 1- 4. The Summary statistics are calculated for all the samples (A, B, C and D). It can be seen from tables 1-4 that there is a Small value of the standard error which indicates that results of all the samples were accurate and the distribution of the trials around the mean of each sample is small.

Because we wish to test the equality of the Means and to assess the differences in the Means, we use the one-way ANOVA procedure with multiple comparisons. Generally, we would choose one multiple comparison method as appropriate for our data.

Table 5 represents the results of the One-way ANOVA analysis from which it can be seen from the that the p-value is closed to 0.002 which indicates that there is a significant difference between the means for the four samples and not all the Means are equal when the significant level (*alpha*) set at 0.05.

Multiple comparison results are presented as a grouping table in table 6. Using the grouping information table to view, in a summarized format, groups of factor level means that are not significantly different. Levels that share a letter are not significantly different. Conversely, if they
The multiple comparison results presented (table 6).

Tukey Method used to compare between means of each sample. Groups do not share a letter are significantly different, in our case group B,C,D represent factors that are significantly affect the amount of needle deflection which is:

B = needle tip design.
C = insertion technique.
D = thickness of tissue.

Where factor A = angle of insertion, has the least effect on amount of deflection. From the box plot, A and D are similar, and B and C are also similar (chart 1).

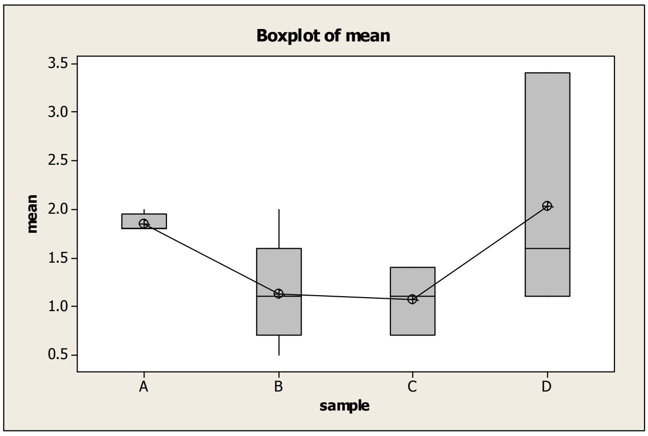

Chart 1.

Another way to analyse the data we carried out the One-way ANOVA: amount of variation versus *mean of all trials (table 7)* The P-value in this table was very close to 0.0 which indicates that there is difference between the Means of each try. Again Grouping Information was done using Tukey Method (Table 8). Tukey Method was used to compare between means of each try. The results obtained in our case shows that means that do not share a letter are significantly different. So values like (3.4),(0.7),(1.8) and (2) are significantly different.

Where:

- (3.4) is the mean of sample (D - 3) where we used thickness of tissue as 3.5 cm.
- (0.7) is the mean of both subsamples. (B - 2) is the sub sample where we used 27 gauge needle of modified tip design. (C - 2) is sub sample where we used rotational technique of insertion.
- (1.8) is the mean of all subsamples (A - 1)(A - 3)(A - 4) , that is when angle of insertion are (30 – 40 – 45 degree).
- (2) is the mean of subsample (A – 2) , that is when angle of insertion is 35 degree.

It can be seen that (3.4) differs with all remaining means while the rest shows some similarity and difference with others using Tukey 95% Simultaneous Confidence Intervals. All pair-wise Comparisons among levels of Mean (Individual confidence level = 99.79%), indicates that there is 99.79% difference between Means as shown in chart 2. In this chart, circles represent the Means and the circles which they are not in straight line which represent difference exist among means of tries. It has shown that (3.4) is the only Mean that has no similarity with any other Means (chart 2).

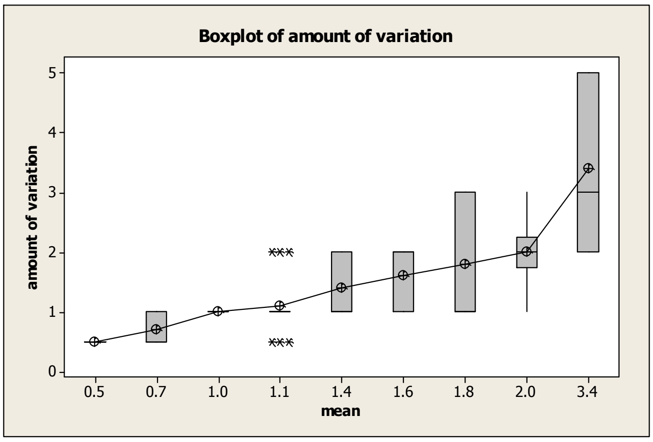

Chart 2.

Discussion

We selected agar -agar material in our study as K Yoshimura[16] stated in his research that Agar -agar have relaxation times similar to those of human tissue and it is a uniform material. In sample A, we suggested that may be changing the angle of insertion, amount of needle deflection was not significant and we concluded that almost no effect of angle of insertion using same gauge length.

Previous studies of dental needle penetration in vitro have demonstrated that the amount of deflection was inversely proportional to needle gauge, thicker the needles, lesser the deflection was[15]. While Dr.Robinson[17], suggested that deflection is more related to type of alloy used for manufacture rather than to the gauge .It has also been reported that needle gauge and relative flexibility or resilience of needle shaft are the physical characteristics that affect needle deflection[18]. In a sample B, we used 27 gauge and 30 gauge needles of same type of alloy used for manufacturer.

We concluded that similar results were obtained with gauge 27 with less amount of deflection than gauge 30 of same length. Jaske and Boshart[19] tested a unique needle tip design. Needle was bevelled on 2 opposite sides of the shaft, placing needle tip at the approximately the centre of long axis. They concluded that tip design is more critical to reduce the amount of deflection than tip diameter[19].

In sample B, we made a modification in to the tip of conventional needle by having two bevel one on each side so we will have a pointed tip for tissue penetration and deposition of solution will be equal around the tip and this bi-bevelled needle tip had markedly less amount of deflection in comparison with conventional tip of same gauge.

The rotational insertion technique provided greater accuracy of placement of needle with minimum deflection[20]. In sample C, we tried 3 different techniques of insertion, first is the conventional technique (linear), second is the rotational technique , third one is the technique, we introduced for the first time (insert needle with bevel away from base, then after fully insertion rotate the bevel toward the base). We concluded that rotational technique has the minimum amount of deflection compared with other techniques. Mark[20], stated that Insertion distances of 25 mm is typical for inferior alveolar block. In sample D, we used 3 moulds of different height (2.5x2x2cm) (3x2x2cm) (3.5x2x2cm). Changing the mould thickness represent the change in the amount of tissue thickness clinically. We found that the deflection of the needle is directly proportional between thicknesses of tissue. The success of local anaesthesia in dentistry is multi-factorial .One of the most challenging of all local anaesthesia injections is the inferior alveolar nerve block .Not all anaesthesia failure are related to needle deflection . However, needle deflection has been identified as one of the causes that can reduce the accuracy of predictable anesthesia[19].

Entire inferior alveolar neurovascular bundle has a diameter of less than 2.2mm[21]. Anaesthetic solution should be deposited within 1 mm of target nerve[22] where in this study we had some needle deflected up to 5 mm; small deviation from the intended target may have a negative effect on success of inferior alveolar nerve block[21].

This study was conducted to investigate the cause-and-effect relationship between many factors and needle deflection.

Conclusions

These are some the following findings which were obtained

1- Thickness of the tissue has significant effect on the amount of needle deflection.

2- Bi-bevelled needle tip has less amount of deflection in comparison with conventional needle tip of the same gauge.

3- Rotational insertion technique has minimum needle deflection among other techniques of needle insertion.

4- Direct proportion exists between gauge of needle and amount of deflection.

5- The angle of insertion has the least effect on amount of deflection.

6- Combination of using bi-bevelled needle tip and rotational technique would give the least amount of needle deflection.

Declaration of Interest

The authors report no conflict of interest and the article is not funded or supported by any research grant.

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Variable* amount of variation	Try	count	mean	SE mean	St Dev	Minimum	Maximum
	1	5	1.100	0.245	0.548	0.500	2.000
	2	5	0.700	0.122	0.274	0.500	1.000
	3	5	1.600	0.245	0.548	1.000	2.000
	4	5	1.100	0.245	0.548	0.500	2.000

Table 1. Results of sample A.

Variable* amount of variation	Try	Count	Mean	SE mean	St Dev	Minimum	Maximum
	1	5	1.800	0.490	1.095	1.000	3.000
	2	5	2.000	0.316	0.707	1.000	3.000
	3	5	1.800	0.374	0.837	1.000	3.000
	4	5	1.800	0.490	1.095	1.000	3.000

Table 2. Results of sample B.

Variable* amount of variation	Try	Count	Mean	SEmean	St Dev	Minimum	Maximum
	1	5	1.100	0.245	0.548	0.500	2.000
	2	5	0.700	0.122	0.274	0.500	1.000
	3	5	1.400	0.245	0.548	1.000	2.000

Table 3. Results of sample C.

Variable* amount of variation	Try	Count	Mean	SE mean	St Dev	Min	Max
	1	5	1.100	0.245	0.548	0.500	2.000
	2	5	1.600	0.245	0.548	1.000	2.000
	3	5	3.400	0.678	1.517	2.000	5.000

Table 4. Results of sample D.

Source	DF	SS	MS	F	P
Sample	3	12.332	4.111	5.36	0.002
Error	66	50.654	0.767		
Total	69	62.986			

Table 5. One-way *ANOVA:* amount of variation versus each sample.

Sample	N	Mean	Grouping
D	15	2.0333	A
A	20	1.8500	AB
B	20	1.1250	B
C	15	1.0667	B

Table 6. Grouping Information Using Tukey Method.

Source	DF	SS	MS	F	P
Sample	8	31.586	3.948	7.67	0.000
Error	61	31.400	0.515		
Total	69	62.986			

Table 7. One-way ANOVA: amount of variation versus mean.

mean	N	Mean	Grouping
3.4	5	3.4000	A
2.0	6	2.0000	B
1.8	15	1.8000	B
1.6	10	1.6000	B C
1.4	5	1.4000	B C
1.1	15	1.1000	B C
1.0	3	1.000	B C
0.7	10	0.7000	C
0.5	1	0.5000	B C

Table 8. Grouping Information Using Tukey Method.