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다양한 잇솔질 방법에 따른 잇솔질 압력 분석

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<Abstract>

Analysis of Toothbrushing Force on Various Brushing Method

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The aim of this study was to carry out the comparative analysis of the brushing force following various brushing techniques by toothbrush mounted pressure sensing unit. The study group consisted of 10 dental hygienist participants. The brushing forces (on buccal area of each first molar) were monitored on 8 different kinds of brushing techniques; Fones, Bass, Rolling, Scrub, Charters, stillman, Modified bass and Modified stillman. In Bass, Charters, Fones and Scrub method, force distributions showed a small gap of maximum and minimum value (Max/Min) while a big difference was noted in Modified bass, Modified stillman, Rolling and Stillman methods. Especially, the biggest difference of Max/Min value was observed in the area of lower left first molar. In conclusion, highly delicate manual skill is needed in showing big error range of force distribution. It means that careful force needs to be focused during toothbrushing instruction when a delicate manual skill was carried out.

Key words : Toothbrushing, Monitoring system, Gyroscope, Accelerometer magnetic sensor

Ⅰ. INTRODUCTION

Tooth brushing is essential for removing oral plaque and biofilm in order to maintain oral hygiene[1)]. Toothbrushing is the most basically, economical and easy method for oral care[2,3)] and its force is an important factor to remove oral plaque. However, a lot of people think that it is difficult to clean their teeth sufficiently.

Even though they are engaged in oral hygiene thoroughly, they experience plaque in dental practice. This is why the toothbrushing instruction should be efficiently carried out.

It has been proved the relationship between brushing and plaque removal[4)], when toothbrushing force is increased, more effective dental plaque removal[1)]. However, gingival recession may be associated with periodontal disease or related to mechanical toothbrushing force[5)]. Several experimental and clinical studies support the assumption that excessive force in brushing is partly responsible for the origin of toothbrush trauma[6)].

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Especially, excessive toothbrushing force is critical factor for gingival recession[7-9], and it is reported that gingival recession frequently occurred in children and elderly and is increased with age[10].

Among the toothbrushing methods, the Scrub method is known to be the most etiological causes of gingival recession[1,11,12]. When the Scrub method was applied, gingival recession occurs mainly in the buccal surface[13]. In addition, the excessive mechanical brushing force induces the exposure of cervical dentin, resulted in teeth hypersensitivity which is one of the causes of tooth pain[14]. For denuded dentin in cervical area due to continuous and forceful toothbrushing, conservative restoration is needed, however, its long-term retention is hard to be expected.

Therefore, in order to enhance the oral hygiene with minimizing the damage of oral tissues, correct toothbrushing technique with appropriate force control is required.

The present study was designed to comparative force distribution in various toothbrushing methods; Fones, Bass, Roll, Scrub, Charters, Stillman, Modified bass and Modified stillman. To measure the loading forces, specially manufactured toothbrush, mounting a pressure sensing unit, was used. Eventually, the proposed correct toothbrushing skill and appropriate force would be effective in removing plaque and reducing occurrence of dental disease. The 1st molar which erupted firstly as a permanent tooth, and caries occurred frequently, for present study, was used. It is a key to occlusion and can be used for toothbrushing instruction (TBI), which is another reason why we choose this one.

II. MATERIALS AND METHODS

1. Study population and experimental design

Ten female dental hygienists were selected. Their ages were ranged 25 to 34 and the average age was 31.2. Their term of service was 2 to12 years as a dental hygienist and their average career was 7.2 years. Based on the references, the 8 different kinds of toothbrushing methods; Fones, Bass, Roll, Scrub, Charters, Stillman, Modified bass and Modified stillman were applied to the buccal surface of every first molar for 20 seconds. During the process of toothbrushing, the force data of brushing was recorded in computer system through load cell mounted toothbrush.

For the posture of volunteers', mannequin's head was raised and rotated to the right direction at 30 degrees with a horizontal to the bottom of occlusal surfaces when brushing the first molars of upper and lower parts on the right side. Mannequin's head was rotated to the left direction with a same degree for the rest molars. The participants were positioned on the direction of the mannequin's head at 10:30 to carry out the toothbrushing on left upper first molar and left lower first molar. To the right upper and lower first molar, participants were seated to the direction of the mannequin's head at 7:00. This position is the direction in which dental hygienist carry out TBI to the patients in clinic.

2. Assessment of brushing force and Data acquisition

Force distribution during toothbrushing was achieved, using by Load cell mounted at a plastic cantilever bridge between holder or body and head of the self-manufactured manual toothbrush. Flexing of the brush head was translated into different voltages through a strain amplifier, which were then monitored by a special software (K&C wellbeing Corp, Gwang Ju, Korea) and transferred to Microsoft Excel® software.

Prior to each brushing session, force level was calibrated for standardization.

3. Toothbrushing method

To analyze the brushing force on each toothbrushing method, Fones, Bass, Roll, Scrub, Charters, Stillman, Modified bass and Modified stillman were carried out according to each instruction. Brief instructions were as follows; **1) Fones method:** Fones method have described in 1934, effective for young children, and don't require complex brushing technique. The teeth were closed and the toothbrush is positioned inside the cheeks. The toothbrush is moved in a circular motion over both the upper jaw and low jaw teeth[15]. **2) Bass method:** Bass method was introduced in 1954 and had effects for removing in the subgingival sulcus plaque. The bristles must be located at a 45°angle to the gingiva and it is inserted 1−2 mm into gingival sulcus. And toothbrush must be moved with short horizontal vibration, back and forth motion[15,16]. **3) Roll method:** The roll method is easily performed and is the most proper when the general public has normal oral health. The bristles are positioned well up on the gingiva. The side of the toothbrush are pressed against the tissue and concurrently rolled occlusal surface against the gingiva[19]. **4) Scrub method:** Scrub method is a usual toothbrushing method on cleaning of occlusal surface[15]. The toothbrush is located perpendicular to the buccal surface of first molar and then moved to a horizontal back and forth direction. **5) Charters method:** Charters method was introduced in 1928, mainly recommended to orthodontic patients to clean brackets and bands[16]. The bristles are placed at 45°angle to the tooth surface and directed toward to the occlusal surface. And a gentle horizontal vibratory motion with back and forth motion is implemented. **6) Stillman method:** It was introduced in 1932, designed gingival massage and stimulation of the soft tissue as well as for removing the cervical areas plaque of the teeth. A toothbrush is located to teeth apical direction at a 45 angle, move to tooth first molar buccal surface with vibration back and forth[15]. **7) Modified bass method:** Modified bass method has significantly effective in removing subgingival and interdental area plaque[17] and recommended to prevent periodontal lesions[18]. The toothbrush is positioned same to the Bass method. The brush was set at a 45°angle to the gingiva marginal and inserted to 1−2 mm into gingival sulcus. After small vibration, rotation stroke in the direction of the occlusion surface. These motion sequences need skill and attention to technique[19]. **8) Modified stillman method:** The Modified Stillman method is recommended for cleaning in soft tissue with progressing cervical abrasion and dentin exposure in order to prevent tissue damage. The toothbrush is located same to the Stillman method. The brush was set at a 45°angle to the teeth apical direction, after move to tooth first molar buccal surface with small vibrates. As brush reach a buccal surface, brush are rotation stroke in the direction of the occlusion surface.

4. Statistical analysis

The distributions among force of toothbrushing were evaluated and each force of toothbrushing distributions drew a Box plot to show the result using a SPSS Statistics version 21.0 (IBM Corp, Chicago, Illinois, USA).

III. RESULTS

1. Data acquisition of individual toothbrushing patterns on various brushing method

The graph shown by visualizing the power during

toothbrushing could be identified. It was possible to confirm the number of brushing performed for 20 seconds through repeated cycles. For the relapsed time of one cycle in every method, it took 0.45 sec on Bass (Fig. 1a), 0.3 sec on Charters (Fig. 1b), 0.4 sec on Fones (Fig. 1c) and 0.4 sec on Scrub (Fig. 1g). And the other method; Modified Bass (Fig. 1d), Modified stillman (Fig. 1e), Roll (Fig. 1f) and Stillman (Fig. 1h), which showed relatively high force level, took 1.6, 3.3, 0.9 and 4 sec each by each for one cycle. The Box plots showed the force distribution and their distribution, for further study, was divided into two groups. Their criteria was based on the force value ±1.5N. The Bass, Fones, Charters and Scrub which have relatively simple motion (using just one motion), that is horizontal scrubbing, vibration and rolling, showed the force distribution ranged 1.5~3N (Fig. 1a, b, c, d). However, the methods (Modified bass and Modified stillman) composed of two combinating motion showed the force distribution ranging 0.3~4.5N (Fig. 1d, e). The Roll which needs turning power was calculated to 0.01~3.7N (Fig. 1f). And Stillman method which the brush should be placed on gingiva with an 45 degree, followed by vibration to toothsurface, needed high force and showed big differences of error limit as ranged 0.01~1.5N (Fig. 1h). 1.5N of force was calculated for Modified stillman and 1N for Stillman. Additionally, the force was sharply changed 2N to 4N at a turning point of rolling after vibration. The Roll showed the force change 0.1N to 3.5N for rolling.

This kind of force distribution was reconfirmed in Box plot (Fig. 1i, j). The value of Minimum to Maximum (Min to Max) showed 0.9 to 1.5N (Fig. 1i), which were in the error limit of ±1.5N in Bass, Fones, Charters and Scrub method. For Modified bass, Modified stillman, Roll and Stillman, there showed the uncommon force distribution as a Min. to Max. (0.01N to 4.5N) (Fig. 1i). All methods except the Roll showed 2N, which were in median value (Fig. 1j). Considering the force distribution of every method, Scrub was the lowest one and Roll showed the highest value (Fig. 1j).

2. Statistical analysis of toothbrushing force

The force distribution of applied toothbrushing were analyzed by statistics on the basis of average with Min. and Max. value (Table 1). Scrub, on right upper first molar, showed a Min. 1.5N and Max. 1.805N, which was the narrowest distribution of force, while Roll showed the widest distribution of force as Min. 0.175N and Max. 2.335N (Fig. 2a). Considering the other area, on right lower first molar, Charters showed the narrowest gap as a value of 0.2N and the big difference as 2.1N for Modified stillman (Fig. 2b). The Bass and Charters, on the area of left lower first molar, showed the lowest value as a 0.3N while 1.5N for Roll (Fig. 2c). For the right lower first molar area, Bass and Charters could be monitored as 0.3N, but 1.5N for Modified bass (Fig. 2d).

Taken together, the force distribution of Bass, Scrub, Charters and Fones were calculated less than ±0.5N of mean, however, Stillman, Modified stillman, Modified bass and Rolling were observed as more than ±0.5N of mean.

The value of Min. and Max. was transformed to numerical value and delineated graphically, which showed the force distribution at a glance. In right upper first molar, the value of Min. to Max. in Scrub designated as 1.5 to 1.85N, the lowest level in present study. In contrary, Roll showed the Min. to Max. value as 0.175N to 2.335N, the highest level. The Charters and Modified bass showed 1.16 to 1.38N and 1.138 to 2.295N respectively in left upper first molar. Considering the left lower first molar, the Bass showed the lowest force distribution as 1.145 to 1.74N, however, the Roll the highest one as 0.23 to 1.72N. On right lower first molar, 1.75 to 1.885N for Bass and 0.345 to 2.53N for

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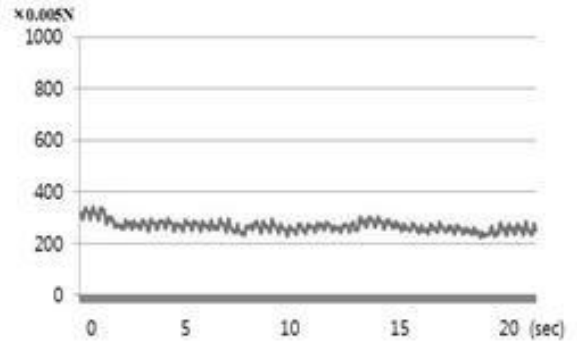
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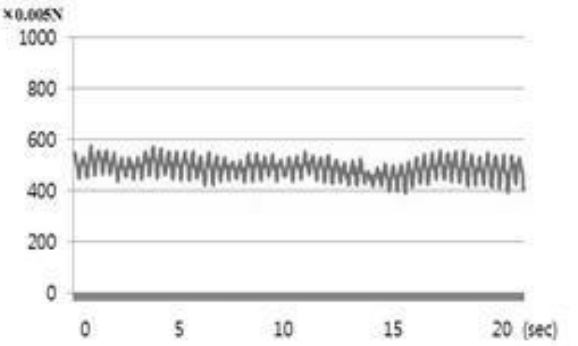
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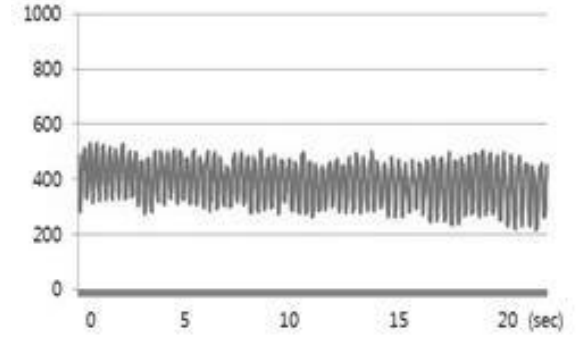
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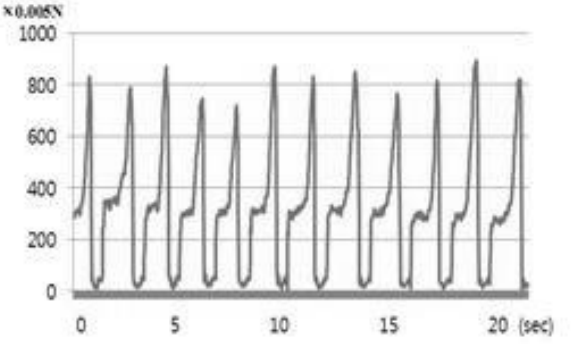
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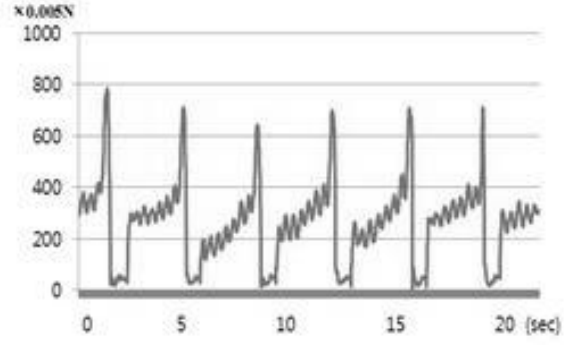
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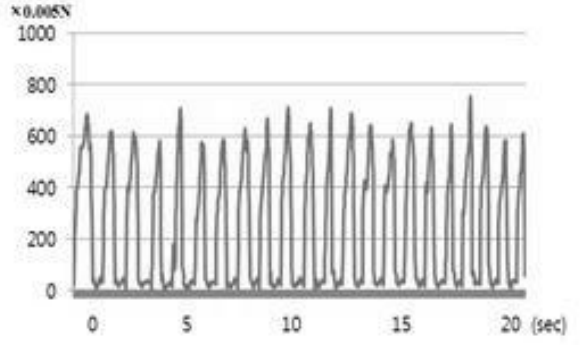
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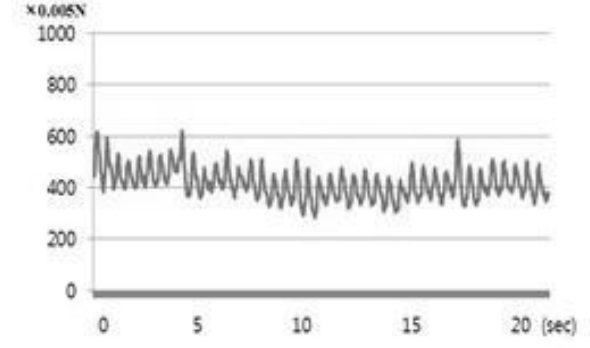
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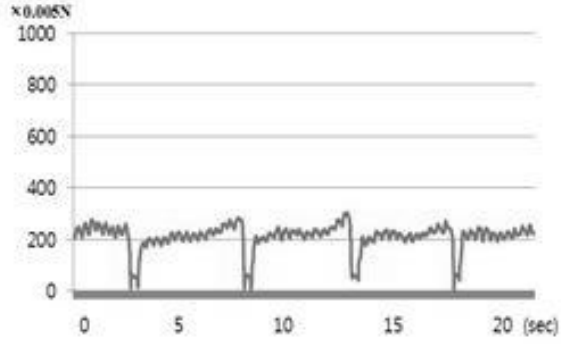
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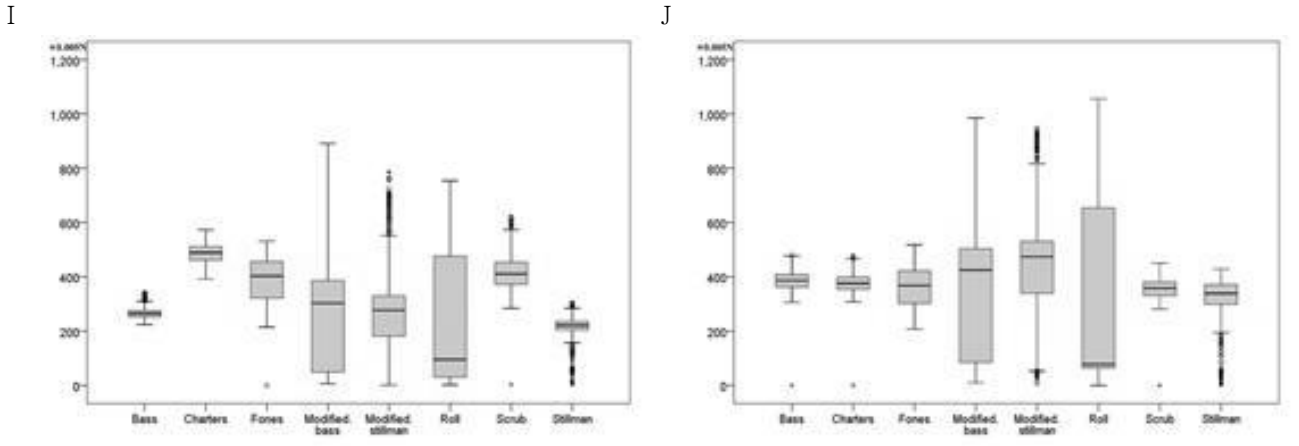

Figure. 1. The force sensing trace on each toothbrushing method by one of representative. The force is measured at left lower first molar during 20 seconds according to instruction of each toothbrushing method. Graph were presented on (a) Bass, (b) Charters, (c) Fones, (d) Modified bass, (e) Modified stillman, (f) Roll, (g) Scrub and (h) Stillman method.

A statistical analysis of the force-time trace analysed from the each graph. The Typical schematic box plot showed means of statistical distribution of participant toothbrushing force. The boxes represent the 25.0, 75.0 percentile with the inner line defined as the median. Mim. and Max. value are represented by horizontal lines; (i) Left lower first molar and (j) Left upper first molar.

Roll were shown.

IV. DISCUSSION

The present study was designed to evaluate the force distribution during toothbrushing by the analogy of various brushing methods. Through the toothbrush bristle axis which is coupling with load cell, applied forces were obtained as an each brushing was carried out. To survey the delineating graph patterns, toothbrushing cycles were calculated and distributions of applied forces were analyzed for indicated time. There focused on the brushing techniques, in previous study, to enhance the plaque removal and to minimize the oral tissue damage[19-21]. Also, 3N (Approximately 300g) is the most effective for plaque removal, however, gingival pain and bleeding may be caused with the power exceeding 3N[13]. Lindhe et al. reported that force over 4N had the bristle bended and had a hard time for appropriate brushing[15]. Their suggestion implicated the importance of applied force on teeth or gingiva. However, it is very hard to calculate the applied force during brushing. Additionally, in view of force as toothbrushing instruction was doing, there was a limitation for explanation to patients. To resolve these problem, specially designed toothbrush was devised to sense and collect the loading power in present study. Fig. 1. showed the force distribution, cycle and it's velocity for 20 sec during toothbrushing. The Bass, Charters, Fones and Scrub, which consisted of one motion; vibration or scrubbing, consumed 0.3~0.45 sec, which were calculated to relatively short time. However, the Modified bass and Modified stillman, which needed combining motions of vibration and rolling, the Roll required the power of turning wrist and the Stillman which should keep vibration at the gingiva and tooth surface took 0.9~4 sec. These results showed that the easier the technique is done, the shorter time is

Table 1. Recorded numerically force value of toothbrushing. Toothbrushing force data from the Min., Mean and Max. were showed the result numerically(Measure: N).

Toothbrushing method		Right upper first molar	Left upper first molar	Left lower first molar	Right lower first molar
Bass	Min.	1.46	1.86	1.425	1.885
	Mean	1.67	2.07	1.575	2
	Max.	1.875	2.275	1.74	2.175
Charters	Min.	1.575	1.16	1.69	1.395
	Mean	1.825	1.265	1.845	1.5
	Max.	2.055	1.38	2.01	1.605
Fones	Min.	1.255	1.1	1.095	1.175
	Mean	1.5	1.335	1.36	1.405
	Max.	1.755	1.53	1.61	1.585
Modified. bass	Min.	0.62	0.81	0.715	0.86
	Mean	1.45	1.83	1.42	1.765
	Max.	2.47	2.91	2.165	2.585
Modified. stillan	Min.	0.585	1.135	0.46	0.775
	Mean	0.985	1.785	1.165	1.61
	Max.	1.53	2.295	1.855	2.295
Roll	Min.	0.175	0.275	0.23	0.345
	Mean	1.1	1.145	0.865	1.39
	Max.	2.335	2.24	1.72	2.53
Scrub	Min.	1.52	1.57	1.645	1.48
	Mean	1.645	1.74	1.405	1.71
	Max.	1.805	1.88	2.015	1.88
Stillman	Min.	0.645	0.845	0.685	0.835
	Mean	1.15	1.485	0.945	1.335
	Max.	1.49	1.795	1.21	1.705

relapsed. However, the velocity of toothbrushing cannot affect the damage of oral soft tissue and tooth abrasion[22,23]. That's why the harm to oral tissues by toothbrushing may not be happened by repetitive number or the velocity of each cycle.

There occurred the force ranged 0.5N to 5.6N (Fig. 1), which was due to the motional characteristics of toothbrushing. The Bass, Charters, Fones and Scrub

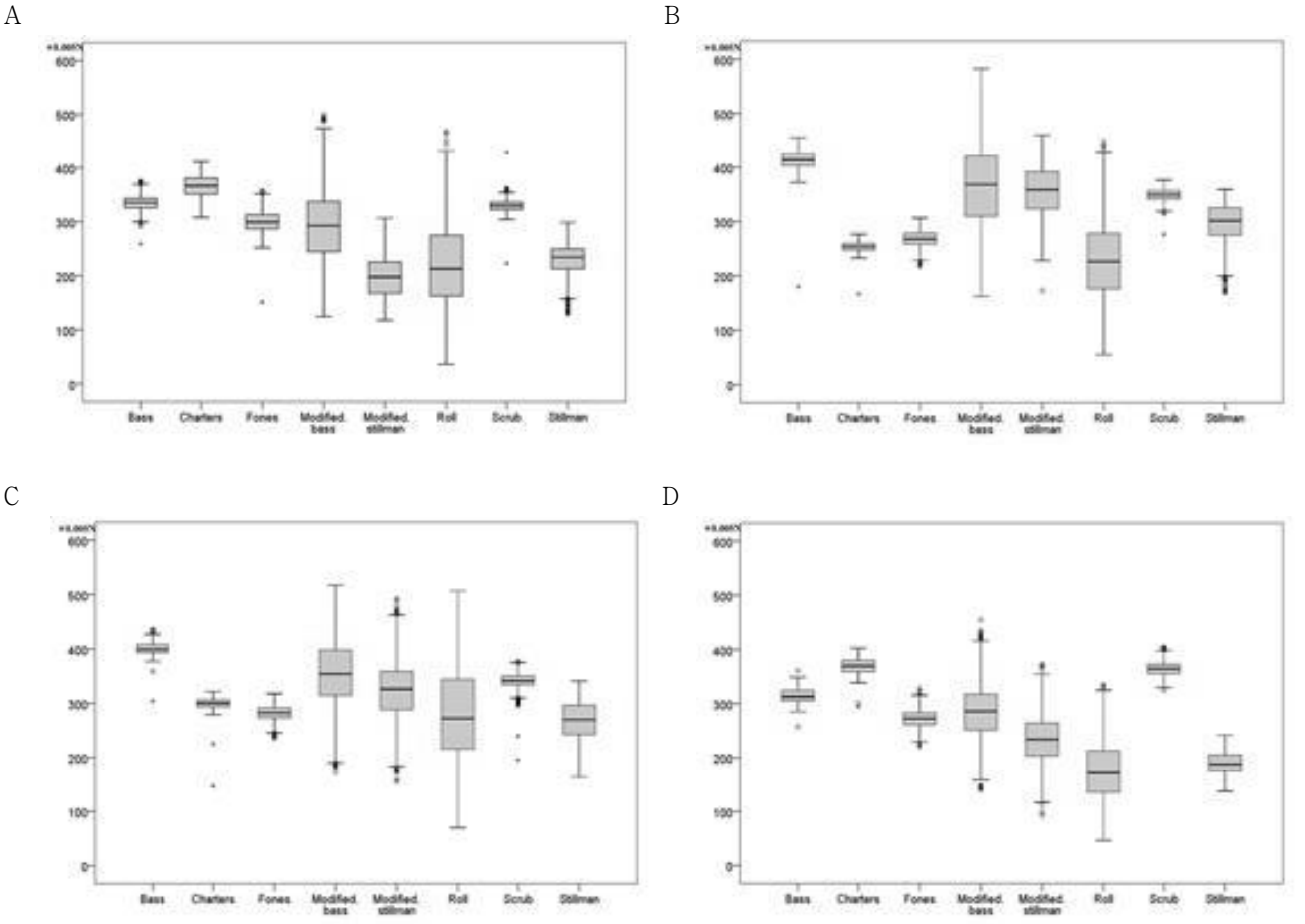

Figure. 2. The force distribution of each toothbrushing methods at indicated region. The Typical schematic box plot showed means of statistical distribution on all participants' toothbrushing force. The boxes represent the 25.0, 75.0 percentile with the inner line defined as the median. Mim. and Max. value are represented by horizontal lines. Data were presented on (a) Right upper first molar, (b) Left upper first molar, (c) Left lower first molar and (d) Right lower first molar.

which delineated with the simple motion without additory motion, might be assumed not to be affected with the force. However, relatively complex motion configured such as Modified bass, Modified stillman, Roll and Stillman were showed the impact force as the every motion was changed. Considering the Modified bass and Modified stillman, 1.5N of external force was applied for vibration after placing the tooth bristles on tooth surface (Fig. 1d, e). Further motion proceeding to vibration was required a sudden force change 2N to4N (Fig. 1d, e). Also, the force was sharply increased 0.1N to 3.5N as the rolling motion was progressed in Roll (Fig. 1f). These results indicated that high forces was arising from the pressure at the crossing point of each motion during toothbrushing. In other words, the bristles should be positioned at the tooth surface not to be slipped down for proceeding the rolling motion. At this point, there occurred the high pressure which might be harm to tooth. In addition, with respect to the average force in all participants, the Bass, Charters,

Fones and Scrub showed the low force level as 0.35N while 1.46N, which ranked 4 times higher, was recorded in Modified bass, Modified stillman, Roll and Stillman.

The median value was different in location. The force value was consistency as 1.5N to 2N in left upper area (Fig. 1j). It is the position of hygienist as they do TBI for patients'and they are right-handed person. They are positioned with embracing patients' head which is more stable and has no inconvenient factor for TBI on left upper area comparing that on other area.

With the present study, we could examine the force distribution during toothbrushing and came to know that there happened higher force in method requiring delicate skills. This indicated that everybody focused on delicate hand movement, not perceived the applied force on tooth. In addition, the position of educator in counterpoise was one of the important factors to keep the applying force stable. Also, the force for motion skill and for keeping bristles on tooth surface for further motion was generated.

Excessive forces happened during toothbrushing may harm to periodontal tissues and hard tissues in oral cavity. Applying force appropriate is very important factor though proper skill during toothbrushing is crucial. Finally, we should emphasize the need to control the force in company with the motion skills.

V. CONCLUSION

In present study, it was designed to evaluate the force distribution during toothbrushing of various brushing methods. To accomplish the present study, specially designed toothbrush mounted load cell was manufactured. It was found that comparative force distribution was varied to every toothbrushing method, dental hygienist's position and where the location brushing is happened. Especially. excessive forces were applied to tooth as the complex motion was proceeded.

Finally, adequate applying force is very important factor with proper skill during toothbrushing.

Acknowledgments

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