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Novel digitally simplified method for detection of best position for attachments placement on tooth surface during clear aligner designing procedures

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Abstract:

Aim of the study: The study aimed to develop a new easy applicable method to detect intended pressure points of the aligner over tooth surface using commercially available software which aid the designer to detect best positions for attachment placement over tooth surface.

Materials and methods: Three different case scenarios were generated using Medit Design software version 3.1.0. These case scenarios were Scenario no.1: controlled tipping of upper right central incisor where thirty models were generated with different positive buccolingual inclination degrees of the upper right central incisor. Scenario no.2: Distal In rotation of upper left central incisor where thirty models were generated with different rotation degrees. Scenario no3: Bodily Movement of upper right central incisor where thirty models were generated with different bodily displacement degrees of the upper right central incisor. STL files (original malocclusion and final virtually planned aligner) of each case were superimposed over each other using smart automatic superimposition tool named Alignment mode. Also, virtual vertical sections were taken in the superimposed STL files to detect the pressure points of the aligner over tooth surface. These pressure points are considered the ideal positions for attachment placement to augment aligner pushing effect.

Results: Regarding scenario no.1(controlled tipping); descriptive statistical analysis showed that there were a pressure points over all the labial surface of the tooth, the highest-pressure points were incisally (-0.652 ± 0.122 middle incisal) while the least-pressure points were gingivally (-0.508 ± 0.005 disto-ginigival). Regarding scenario no.2(distal in rotation); descriptive statistical analysis showed that there were pressure and relief points over the labial surface of the tooth, the highest-pressure points were concentrated distally (-0.145 ± 0.039 disto-incisal) while the relief points were concentrated mesially (0.215 ± 0.022 mesio-incisal). Regarding scenario no.3(bodily movement); descriptive statistical analysis showed that there were variable pressure points over all the labial surface of the tooth, the highest-pressure points were concentrated gingivally (-1.211 ± 0.074 Middle-gingival) while the least-pressure points were concentrated incisally (-0.033 ± 0.047 middle-incisal).

Conclusion: A novel method for detection of the aligner pressure areas over tooth labial surface is conducted by Medit design software through deviation display mode. This method enables the operator to accurately position the

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attachment during designing of home-made aligners to augment a certain movement or limit another tooth movement. Regarding controlled tipping, it is recommended to place the attachment on the middle junction between middle and gingival thirds, as this attachment position will compensate for high pressure at incisal one third and by this way, a more predictable controlled tipping orthodontic tooth movement may be obtained. Regarding bodily orthodontic tooth movement, it is recommended to place the attachment on the middle junction between middle and gingival thirds which will augment more pressure over the cervical portion of the tooth labial surface favoring more root movement.

Introduction:

Esthetic appearance of orthodontic appliance became an important concern for many patients who are seeking orthodontic treatment (1). So, the demand for clear aligner therapy has increased as an orthodontic treatment option with esthetic appearance (2). Continuous development of Clear Aligner Therapy (CAT) is continuous to fulfill the criteria of ideal orthodontic appliance, both bio- mechanical control and best esthetic appearance (3). Regarding bio-mechanical control, orthodontic rotational tooth movement is considered one of difficult orthodontic tooth movement using CAT (4). The usage of attachment improved the predictability of rotational orthodontic tooth movement using CAT that attachment provide push surface over tooth surface which enhance the mechanics of aligners (5). Advancements in computer science and artificial intelligence has enabled many orthodontists to fabricate home-made aligners depending on many soft wares (6,7,8). Yet, these soft wares vary in integrated artificial intelligence capabilities. One of deficient points in designing soft wares is the ability to precisely automatically detect the attachment positions over tooth surface to achieve the desired orthodontic tooth movement (9,10). So, it is a worthy point of investigation to detect the best position for attachment placement that will enhance the effect of CAT.

Aim of the study:

The aim of the study was to develop a new easy applicable method to detect intended pressure points of the aligner over tooth surface using commercially available software which aid the designer to detect best positions for attachment placement over tooth surface.

Methodology:

An archived digital intra-oral scan was used to create different case scenarios. The scan was taken using digital scanner (Medit i700) (11) to a patient who had finished his orthodontic treatment in the orthodontic department, Faculty of Dentistry hospital, Minia University.

Three different case scenarios were generated using Medit Design software version 3.1.0. These case scenarios were Scenario no.1: controlled tipping of upper right central incisor where thirty models were generated with different positive buccolingual inclination degrees of the upper right central incisor. Scenario no.2: Distal In rotation of upper left central incisor where thirty models were generated with different rotation degrees. Scenario no3: Bodily Movement of upper right central incisor where thirty models were generated with different bodily displacement degrees of the upper right central incisor.

STL files of the ninety generated models will be imported in an orthodontic software (3D maestro V6) (figure 1) specific for virtual treatment planning and dental rotation correction without adding any virtual attachments [(12)]. Subsequent virtually reproduced final Aligners of each case were exported and saved as STL files in addition to the STL files of the original malocclusion scans, STL files were imported in an application called (Medit Design) (figure 2). STL files (original malocclusion and final virtually planned aligner) of each case were superimposed over each other using smart automatic superimposition tool named Alignment mode (figure 3,4,5,6). Also, virtual vertical sections were taken in the superimposed STL files to detect the pressure points of the aligner over tooth surface (figure 7,8,9). These pressure points are considered the ideal positions for attachment placement to augment aligner pushing effect.

Deviation display mode in medit design software was used to detect areas of pressure and relief of aligner over tooth surface. Deviation display mode enables the operator to measure the degree of pressure or relief of aligner over tooth surface with numbers, zero number indicates no pressure or relief, positive number indicates releif point and negative number indicates pressure point. Also, a color grading in the deviation display mode indicates the degree of pressure or relief of aligner over tooth surface, yellow color indicates no pressure or relief, dark blue color indicates higher pressure and red color indicates higher relief (figures 10,11,12). Tooth surface in each case scenario was classified into nine measuring areas: (mesio-gingival, middle-gingival, disto-gingival, mesio-middle, middle-middle, disto-middle, mesio-incisal, middle-incisal, disto-incisal) (figure 13).

Data was extracted from measurements of the three case scenarios (controlled tipping, distal in rotation, and bodily movement) from the nine measuring points (mesio-gingival, middle-gingival, disto-gingival, mesio-middle, middle-middle, disto-middle, mesio-incisal, middle-incisal, disto-incisal), then all data were tabulated for statistical analysis.

Figure 1: 3D Maestro Software.

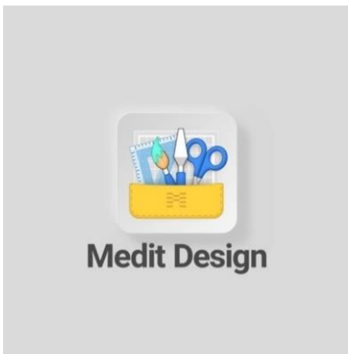


Figure2: Medit Design Software

Figure 3: STL file of the malocclusion.

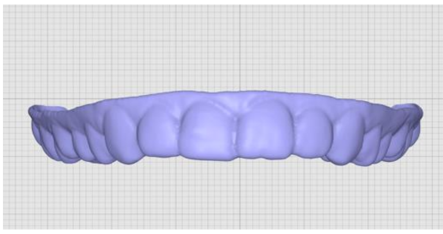


Figure 4: virtually reproduced final Aligner

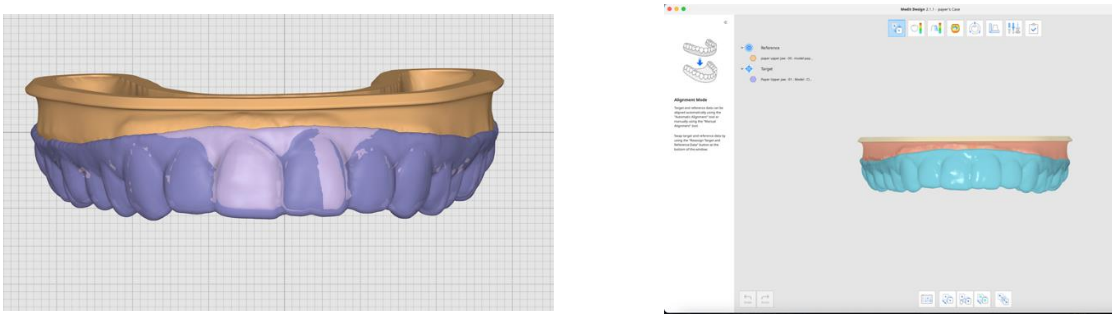


Figure 5,6: superimposition of virtually reproduced final Aligner and STL file of malocclusion

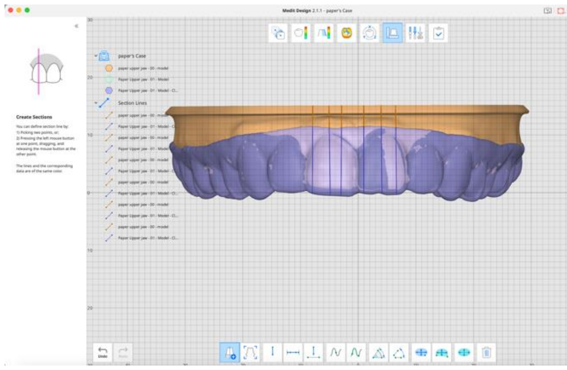


Figure 7: lines of virtual vertical sections of the upper six anterior teeth

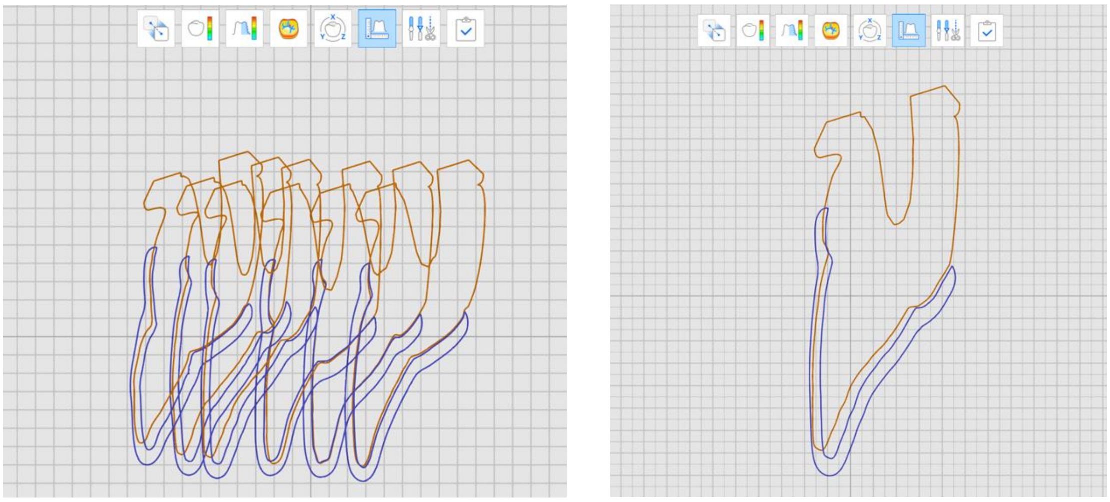
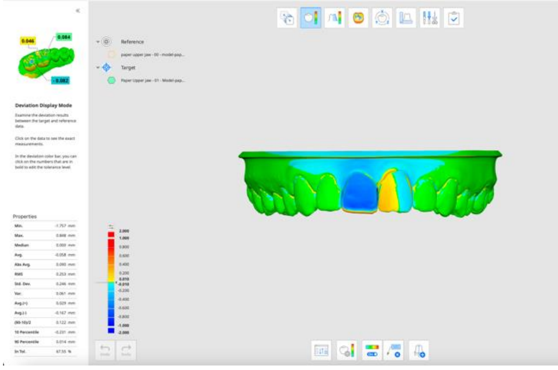


Figure 8,9: virtual vertical sections of the upper six anterior teeth, virtual vertical section of the upper right central incisor



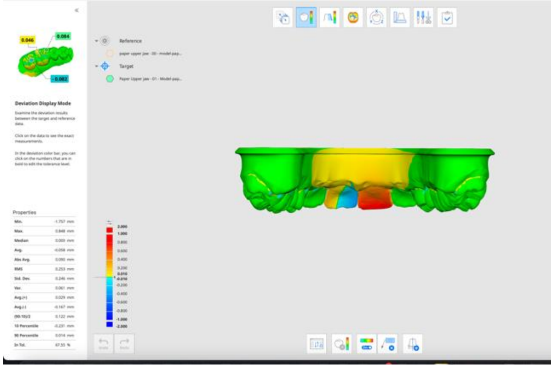


Figure 10,11: Deviation display mode enables the operator to measure the degree of pressure or relief of aligner (yellow color indicates no pressure or relief, dark blue color indicates higher pressure and red color indicates higher relief)

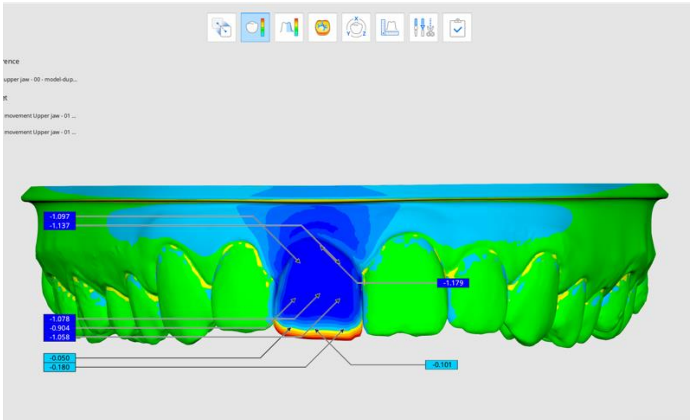


Figure 12: Deviation display mode enables the operator to measure the degree of pressure or relief of aligner (zero number indicates no pressure or relief, positive number indicates releif point and negative number indicates pressure point)

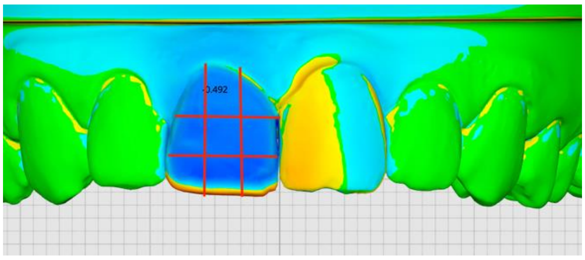


Figure 13: classification of tooth surface into nine measuring areas

Results:

Regarding scenario no.1(controlled tipping); descriptive statistical analysis showed that there were a pressure points over all the labial surface of the tooth, the highest-pressure points were incisally (-0.652 ± 0.122 middle incisal) while the least-pressure points were gingivally (-0.508 ± 0.005 disto-ginigival) (table1) (figure 1).

Regarding scenario no.2(distal in rotation); descriptive statistical analysis showed that there were pressure and relief points over the labial surface of the tooth, the highest-pressure points were concentrated distally (-0.145 ±

0.039 disto-incisal) while the relief points were concentrated mesially (0.215 ± 0.022 mesio-incisal) (table1) (figure 2).

Regarding scenario no.3(bodily movement); descriptive statistical analysis showed that there were variable pressure points over all the labial surface of the tooth, the highest-pressure points were concentrated gingivally (-1.211 ± 0.074 Middle-gingival) while the least-pressure points were concentrated incisally (-0.033 ± 0.047 middle-incisal) (table1) (figure 3).

Table 1: Descriptive statistics of the three scenarios (Controlled tipping, Distal in rotation ,and Bodily movement)

	Uncontrolled tipping No.= 30	**Distal in rotation No.= 30**	**Bodily movement No.= 30**
	Mean ± SD Median (IQR)	**Mean ± SD Median (IQR)**	**Mean ± SD Median (IQR)**
Mesio-gingival	-0.509 ± 0.004 -0.509 (-0.512 – -0.505)	0.145 ± 0.015 0.145 (0.131 – 0.159)	-1.158 ± 0.056 -0.1.137 (-0.1.217 – -1.111)
Middle gingival	-0.513 ± 0.007 -0.512 (-0.52 – -0.506)	-0.001 ± 0.005 0.001 (-0.006 – 0.002)	-1.211 ± 0.074 -1.213 (-1.272 – -1.148)
Disto-gingival	-0.508 ± 0.005 -0.508 (-0.513 – -0.504)	-0.078 ± 0.009 -0.075 (-0.087 – -0.07)	-1.149 ± 0.051 -1.126 (-1.203 – -1.107)
Mesio-middle	-0.563 ± 0.015 -0.564 (-0.577 – -0.549)	0.189 ± 0.008 0.189 (0.182 – 0.197)	-0.917 ± 0.018 -0.913 (-0.935 – -0.903)
Middle middle	-0.564 ± 0.016 -0.561 (-0.58 – -0.549)	0.004 ± 0.003 0.004 (0.0005 – 0.007)	-0.983 ± 0.013 -0.988 (-0.994 – -0.971)
Disto-middle incisal	-0.564 ± 0.015 -0.567 (-0.578 – -0.549)	-0.104 ± 0.01 -0.103 (-0.113 – -0.096)	-0.922 ± 0.02 -0.913 (-0.941 – -0.908)
Mesio-incisal	-0.649 ± 0.012 -0.654 (-0.657 – -0.638)	0.215 ± 0.022 0.213 (0.194 – 0.236)	-0.106 ± 0.058 -0.125 (-0.149 – -0.053)
Middle incisal	-0.652 ± 0.122 -0.655 (-0.662 – -0.639)	0.014 ± 0.002 0.014 (0.013 – 0.017)	-0.033 ± 0.047 -0.013 (-0.067 – -0.008)
Disto-incisal	-0.649 ± 0.011 -0.654 (-0.657 – -0.638)	-0.145 ± 0.039 -0.133 (-0.178 – -0.119)	-0.099 ± 0.054 -0.123 (-0.129 – -0.059)

(Negative values represent pressure areas while positive values represent relief areas)

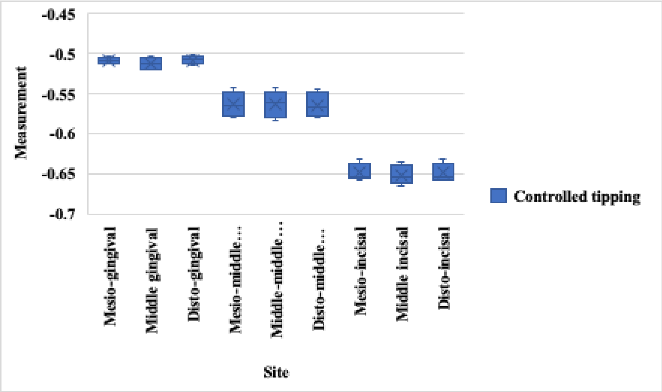


Figure 1: Controlled tipping measurements comparison at different site.

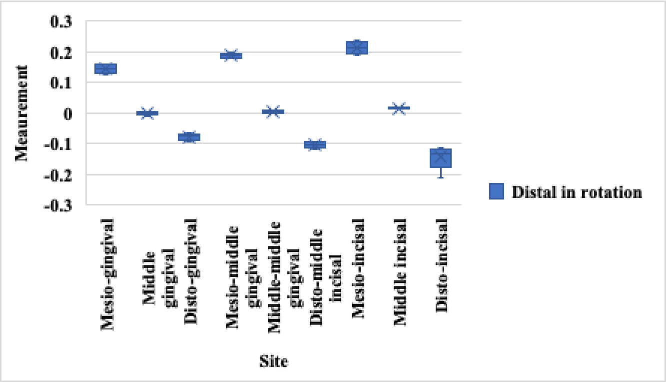


Figure 2: Distal in rotation measurements comparison at different site.

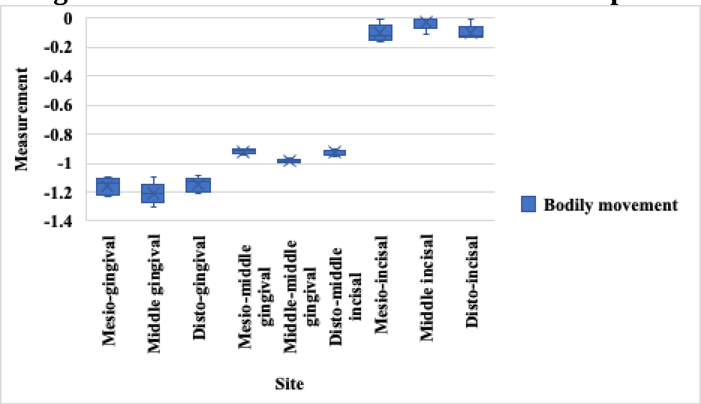


Figure 3: Bodily movement measurements comparison at different site.

Discussion:

This research provided a new method for detection of pressure and relief points of aligner over tooth surface which is considered a promising tool for detection of best points for attachment placement over tooth surface (13,14). Many softwares are commercially available for clear aligner therapy planning through virtual teeth segmentation, virtual teeth movement, attachment positioning, and treatment staging (15,16). These softwares depend on the built-in algorithms (Artificial Intelligence) helping the software for attachment placement (17). As a designer, you can manually place the attachment over teeth surface in certain points serving your intended teeth movements. An archived intra oral scan for a patient who has finished his orthodontic treatment was used to generate different malocclusion STL models using Medit Design software. Three different malocclusion scenarios were designed for upper central incisor tooth (controlled tipping, distal in rotation, and bodily movement). Medit Design cannot be used for aligner therapy designing so, another software (3D Maestro) was for clear aligner designing. Ninety STL files of the three different malocclusion scenarios were exported from Medit Design software and imported in 3D Maestro software. 3D Maestro software was used to generate the final aligners STL files without attachment placement over teeth surfaces. Final aligners STL files were exported from 3D Maestro software and imported in Medit Design software. Original malocclusion STL files and its Final aligners STL files were superimposed using alignment mode. Medit Design software is a new software which has a built-in feature named deviation display mode which depends on Artificial Intelligence to detect degree of interference between different 3D voxels and giving these interference numbers and colours.

Regarding scenario no.1(controlled tipping); descriptive statistical analysis showed that there were a pressure points over all the labial surface of the tooth, the highest-pressure points were incisally (-0.652 ± 0.122 middle incisal) while the least-pressure points were gingivally (-0.508 ± 0.005 disto-ginigival) (table1) (figure 1). Higher pressure of aligner over incisal one third of the labial tooth surface will favor uncontrolled tipping (18,19). So, it is recommended to place the attachment on the middle junction between middle and gingival thirds to compensate for high pressure at incisal one third and by this way, a more predictable controlled tipping orthodontic tooth movement may be obtained.

Regarding scenario no.2(distal in rotation); descriptive statistical analysis showed that there were pressure and relief points over the labial surface of the tooth, the highest-pressure points were concentrated distally (-0.145 ± 0.039 disto-incisal) while the relief points were concentrated mesially (0.215 ± 0.022 mesio-incisal) (table1) (figure 2). So, it is recommended to place the attachment on the junction between the disto-middle third and gingiva-middle third to augment more distal in rotation. It is not recommended to place the attachment more gingival because of the aligner relaxation at the gingival one third is high (20).

Regarding scenario no.3(bodily movement); descriptive statistical analysis showed that there were variable pressure points over all the labial surface of the tooth, the highest-pressure points were concentrated gingivally (-1.211 ± 0.074 Middle-gingival) while the least-pressure points were concentrated incisally (-0.033 ± 0.047 middle-incisal) (table1) (figure 3). It is recommended to place the attachment on the middle junction between middle and gingival thirds which will augment more pressure over the cervical portion of the tooth labial surface favoring more root movement [21,22].

Conclusion:

A novel method for detection of the aligner pressure areas over tooth labial surface is conducted by Medit design software through deviation display mode. This method enables the operator to accurately position the attachment during designing of home-made aligners to augment a certain movement or limit another tooth movement. Regarding controlled tipping, it is recommended to place the attachment on the middle junction between middle and gingival thirds, as this attachment position will compensate for high pressure at incisal one third and by this way, a more predictable controlled tipping orthodontic tooth movement may be obtained. Regarding bodily orthodontic tooth movement, it is recommended to place the attachment on the middle junction between middle and gingival thirds which will augment more pressure over the cervical portion of the tooth labial surface favoring more root movement.

Recommendations:

1. More studies using deviation display mode in medit design software are recommended to assess pressure areas of aligner over tooth surface in different orthodontic tooth movement (intrusion, extrusion, and torque movement)
2. Clinical trials are needed to confirm if the recommendations of attachment positioning according to aligner pressure areas over tooth surface will give more predictable orthodontic tooth movement rather than the automatic attachment placement generated by Artificial Intelligence used in different aligner designing softwares or not.
3. Clinical trials are recommended to compare between the ability of Artificial Intelligence of different aligner designing softwares to accurately place the attachments over tooth surface according to pressure and releif areas of aligner over tooth surface.

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