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ORIGINAL RESEARCH

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Numerical finite element analysis of periodontal ligament after restoration of primary molars with stainless steel crowns

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Abstract

Background: Uncertainty in occlusal height adjustment after restoration of primary molars with stainless steel crowns (SSCs) under general anaesthesia. **Methods**: The objective of this study is to assess the impact of augmented occlusal height on the periodontal ligament (PDL) following the restoration of primary molars with SSCs, utilizing three-dimensional finite element analysis (3D-FEA). Cone-beam computed tomography (CBCT) images of one male and one female child aged 3, 6 and 8 years were selected. The three-dimensional (3D) models were constructed and subsequently grouped as follows: Group A, deciduous molars not restored by SSCs (control group). Group B1, deciduous molars restored to normal occlusion using SSCs. Group B2, first deciduous molars restored to normal occlusion using SSCs. Group B3, second deciduous molars restored to normal occlusion using SSCs. Group C1 utilized SSCs to restore the first and second deciduous molars to an occlusal increase of 1 mm. Group C2 applied SSCs to restore the first deciduous molars to an occlusal increase of 1 mm. Group C3 utilized SSCs to restore the second deciduous molars to an occlusal increase of 1 mm. Group D1 employed SSCs to restore the deciduous molars to an occlusal increase of 2 mm. Group D2, the first deciduous molars, were restored with SSCs to an occlusal increase of 2 mm. Group D3, the second molar was also restored with SSCs to achieve an occlusal increase of 2 mm. Loads were applied at angles of 0, 45 and 90 degrees separately to ten sets of models for each child using 3D-FEA to evaluate the biomechanical effects on the PDL. **Results**: A statistically significant difference in maximum Von-Mises stresses within the PDL was observed between groups B1 and A ($p < 0.01$). A positive correlation was observed between occlusal height following SSC restoration and maximum von-Mises stress in the PDL ($p < 0.01$). The maximum von-Mises stress in the PDL exhibited a positive correlation with the occlusal height of the SSC restorations, and a negative correlation with the loading angle and age ($p < 0.01$). **Conclusions**: It is advised that the occlusal height of molar teeth restored with SSC be maintained at a level within a range of 2 mm.

Keywords

Finite element analysis; Stainless steel crown; Primary molar; Periodontal ligament; Occlusion

1. Introduction

Stainless steel crowns (SSCs) are acknowledged as one of the preferred methods for restoring primary molars compromised by caries affecting the tooth structure [1]. Research shows that the utilization rate of SSCs in China will reach 78% in 2022, an increase of 25% compared to 2013 [2]. They not only restore the morphology and masticatory function of primary teeth but also enhance the proximal relationship with adjacent teeth, thereby reducing the occurrence of malocclusion and other adverse effects [3]. Previous clinical evaluations of SSC restorations have primarily focused on criteria such as retention, secondary caries, and periodontal conditions, with limited attention given to the effects on occlusion post-SSC placement. Recent studies utilizing digital bite analysis (T-Scan III) have shown an increase in occlusal height by 1–1.5 mm following SSC restoration, with occlusal forces reaching equilibrium due to alveolar bone compensation within weeks. However, pediatric patients with postoperative occlusal contacts have exhibited varying occlusal forces during the same period [4–6]. In clinical practice involving dental treatment under general anesthesia, early contacts or occlusal interferences are often unavoidable when restoring carious primary molars with SSCs, especially homonymous molars in the maxilla and mandible.

Research indicates that the periodontal ligament (PDL) serves as a specialized fibrous connective tissue maintaining the periodontal tissues and the homeostasis of surrounding bone and cementum [7–9]. Mechanical stimulation of PDL stem cells can induce osteoclast differentiation; however, excessive mechanical forces beyond the PDL's physiological limits can lead to root resorption [10, 11].

Studying the bio-mechanical behavior of the periodontal ligament following SSC restoration through *in vivo* research poses ethical challenges. Nonetheless, three-dimensional finite element analysis (3D-FEA) replicates oral tissue mechanics, including teeth, periodontal ligaments and bone tissues, under controlled conditions, enabling exploration of various impacts of oral treatments and pathologies [12–18]. This study aims to utilize 3D-FEA to investigate the biomechanical effects of SSC restoration on primary molars following occlusal height increase, providing insights for clinical SSC restorations in primary molars.

2. Materials and methods

2.1 Modeling

Cone-beam computed tomography (CBCT) images were obtained from a sample of six children, comprising one male and one female at the ages of 3, 6 and 8 years. All subjects were free from dental caries, exhibited non-dental anomalies and presented with normal occlusion (the individual normal occlusion). The images were transferred in DICOM format to Mimics Research 21.0 (Materialize Software, Leuven, Belgium). Thanks to Mimics Research 21.0 medical imaging software, the bone structure and teeth were extracted and segmented from the axial, coronal, and sagittal planes of the CBCT images using appropriate grayscale thresholds, as shown in Fig. 1. Save the model in STL format.

2.2 Model surface materialization

The STL format files were imported into Geomagic Wrap 2021 (Geomagic, Luxembourg, IA, USA) for the purpose of reverse engineering. During this process, the dental structures, including the teeth, maxilla and mandible, were subjected to smoothing, and the models were subsequently transformed into surface solids to produce high-quality three-dimensional representations, which were then saved in STP format, as illustrated in Fig. 2. This methodology is of great significance for the accurate modeling of the intricate details of the original bone and dental structures.

2.3 Design and model grouping of SSCs

Transfer the STP files corresponding to the maxilla, mandible and dentition into SolidWorks 2021 (SolidWorks, Waltham, MA, USA). The isotropic surface, thickening, combining and segmenting functionalities are used to construct a PDL measuring 0.20 mm [19], an alveolar fossa, and an SSC 0.14 mm thick, as depicted in Figs. 3,4. The right maxillary and mandibular deciduous molars were selected as experimental subjects to investigate the impact of increased occlusal height following the restoration of molar teeth with SSCs and the influence of different tooth positions in molar teeth restored with SSCs on the PDL. The experimental groupings are as follows: Group A, deciduous molars not restored by SSCs (control group). Group B1, deciduous molars restored to normal occlusion using SSCs. Group B2, first deciduous molars restored to normal occlusion using SSCs. Group B3, second deciduous molars restored to normal occlusion using SSCs. Group C1 utilised SSCs to restore the first and second deciduous molars to an occlusal increase of 1 mm. Group C2 applied SSCs to restore the first deciduous molars to an occlusal increase of 1 mm. Group C3 utilized SSCs to restore the second deciduous molars to an occlusal increase of 1 mm.

Group D1 employed SSCs to restore the deciduous molars to an occlusal increase of 2 mm. Group D2, the first deciduous molars were restored with SSCs to an occlusal increase of 2 mm. Group D3, the second molar was also restored with SSCs to achieve an occlusal increase of 2 mm. The subsequent schematic depicts the methodology for adjusting the SSC bite height, as illustrated in Fig. 4. The models of the experimental groups were saved as X.T. format files.

2.4 Grid construction and material properties

The X.T format files were imported into ANSYS Workbench 2020 (ANSYS, Canonsburg, PA, USA) for model meshing, refinement of mesh size, and model convergence processing. Subsequently, the material and structure of the experimental model were defined as continuous, homogeneous, isotropic and linearly elastic. Based on the mechanical property parameters of teeth and materials listed in Table 1 (Ref. [20–22]), the material properties of each structural component were edited. These 3D models consist of approximately 278,682 to 595,820 elements and 165,310 to 301,015 nodes, respectively.

2.5 Boundary conditions

To more accurately simulate the clinical use of SSCs in the oral cavity, the system configured all contact pairs in the model (alveolar bone with periodontal membrane, tooth with periodontal membrane, tooth with SSC, SSC with periodontal membrane) to be in tight contact. This means that no sliding occurs at each interface during loading. Additionally, the upper jawbone was constrained at the top and the lower jawbone at the bottom. In order to reduce confounding factors, this experiment was performed based on the mean value of the maximum bite force at each age group applied to the SSCs [23]. The forces were analyzed from the 0°, 45° and 90° loads (see Fig. 5) in order to obtain the maximum Von-Mises values for the PDL, as shown in **Supplementary Table 1**.

2.6 Statistical analysis

Ordered logit modeling analysis of inter-group data comparisons was performed using Stata 17.0 (StataCorp Stata, College Station, TX, USA). The experimental groups X_1, loading angles X_2, tooth positions X_3, age X_4 and gender X_5 were selected as independent variables. The maximum Von-Mises stress value in the periodontal ligament was used as the dependent variable Y. The regression equation is defined as $Y = \beta_0$

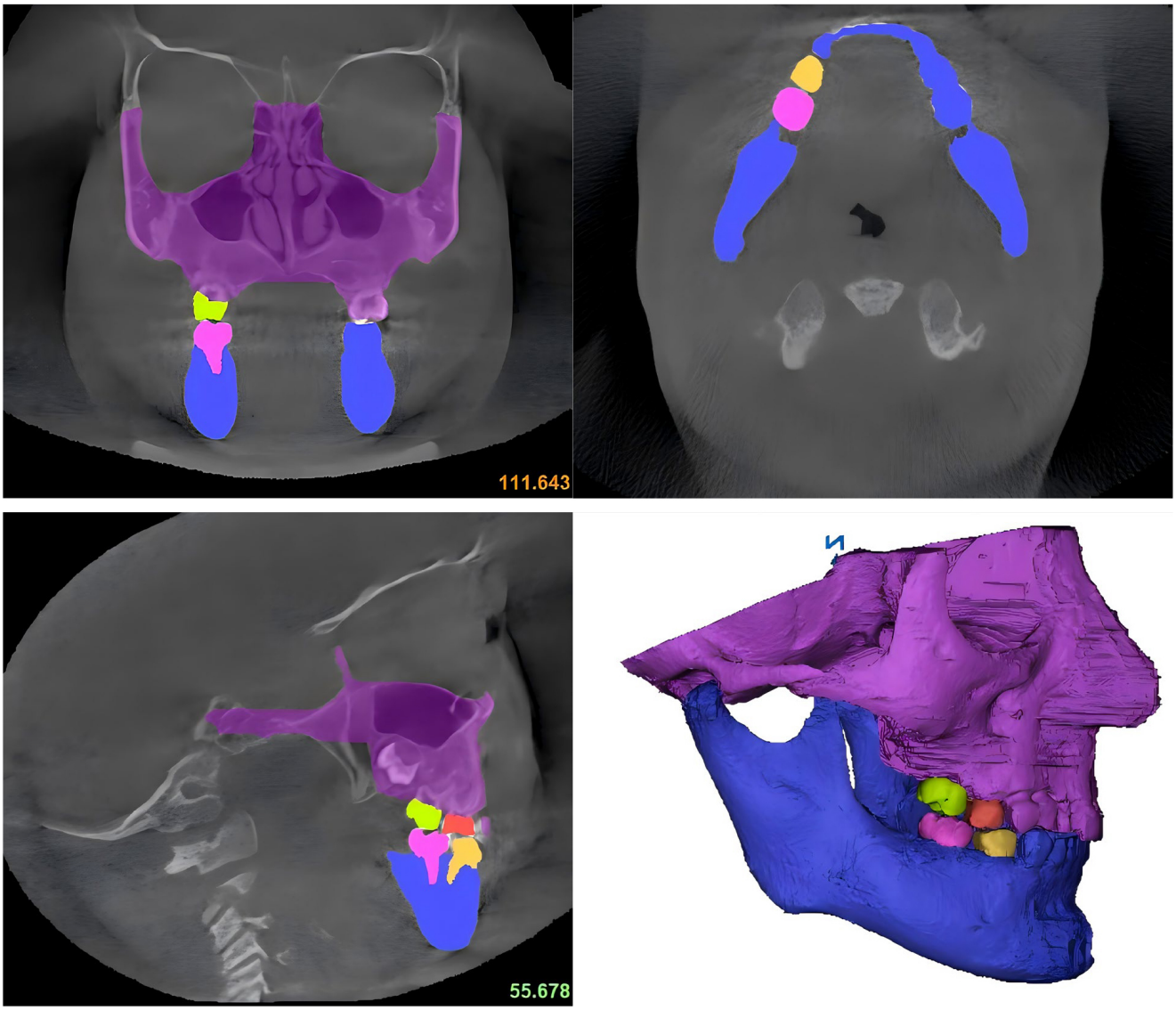

FIGURE 1. CBCT image extraction and preliminary model construction.

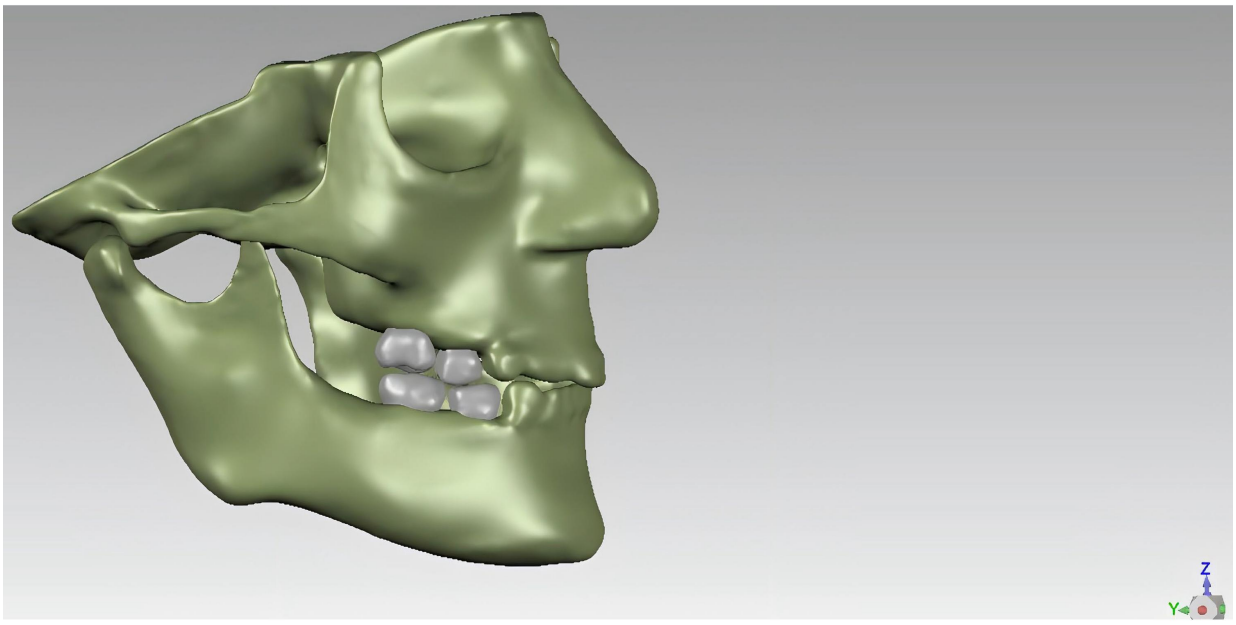

FIGURE 2. Solidified models of the Maxilla, mandible and teeth.

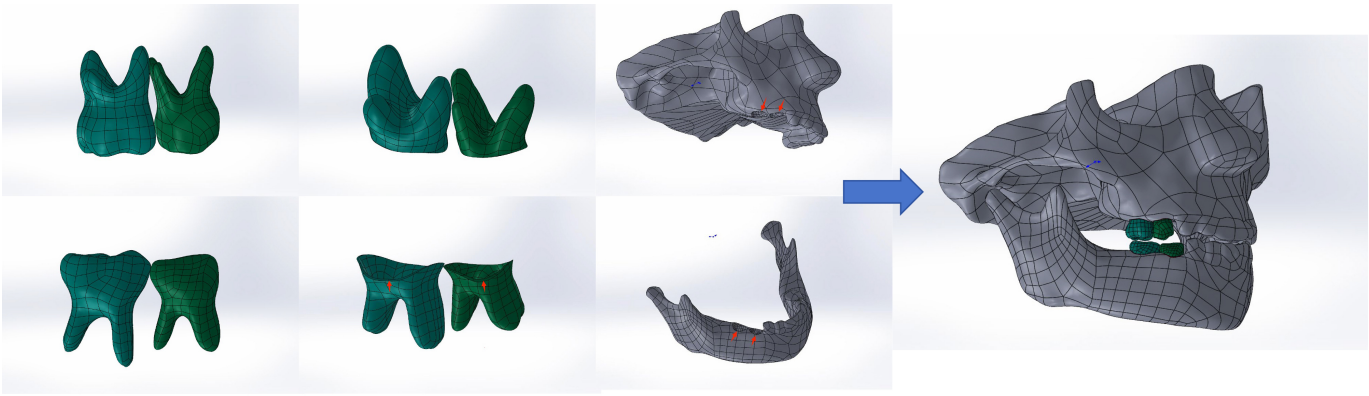

FIGURE 3. Assembly of models of teeth, alveolar fossa, periodontal ligament, maxilla and mandible.

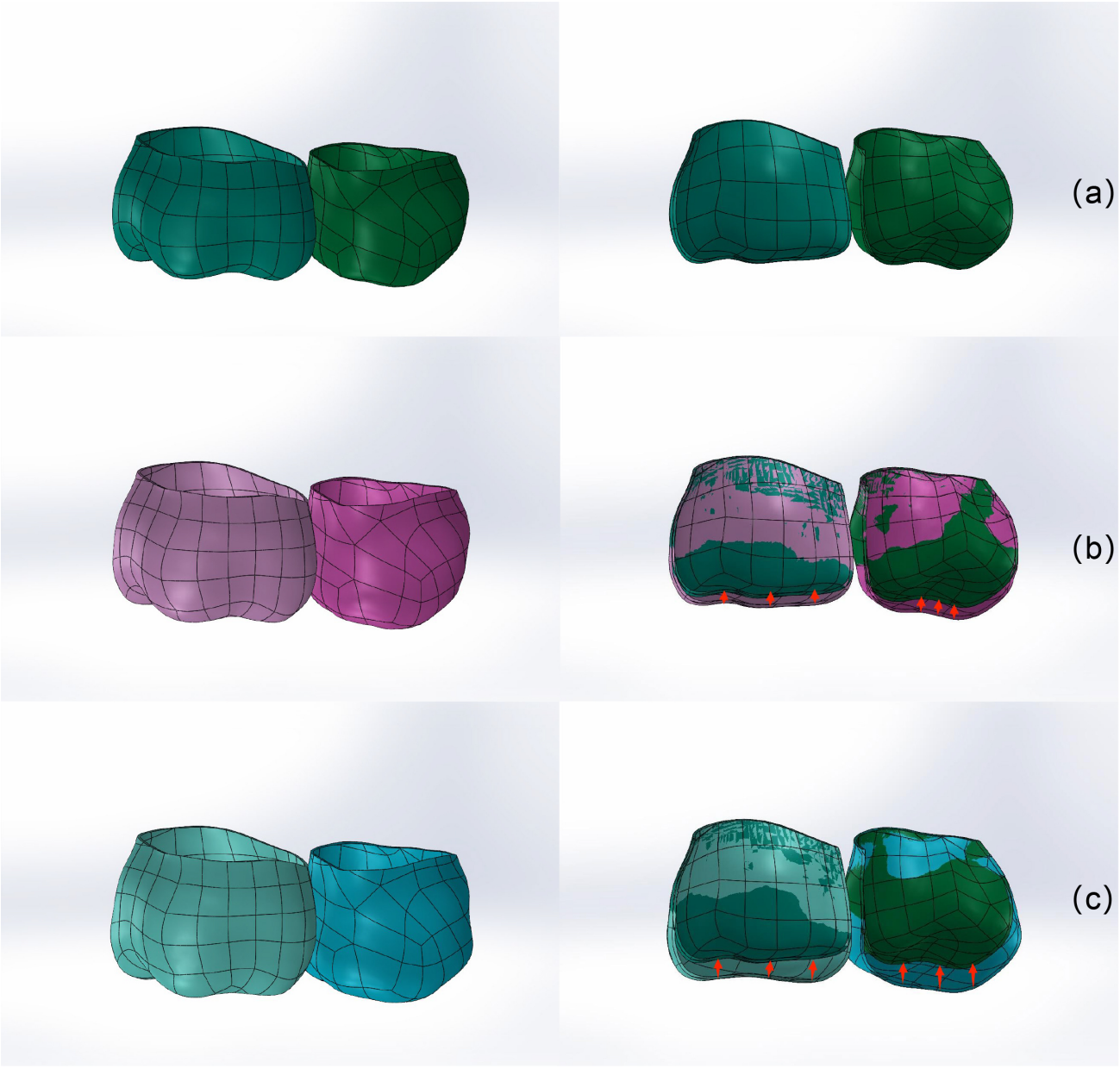

FIGURE 4. A diagrammatic representation of the occlusal height adjustment of SSCs. (a) Normal occlusion, (b) Occlusion increased by 1 mm, (c) Occlusion increased by 2 mm.

TABLE 1. Mechanical performance parameters of teeth and materials.

Structure	Elastic modulus (MPa)	Poisson's ratio
Stainless steel crown	210,000	0.33 [20, 21]
Periodontal membranes	66.7	0.49 [22]
Dentin	18,600	0.31 [20, 21]
Dental enamel	84,100	0.30 [20, 21]
Cortical bone	13,700	0.30 [20, 21]
Cancellous bone	13,700	0.30 [20, 21]

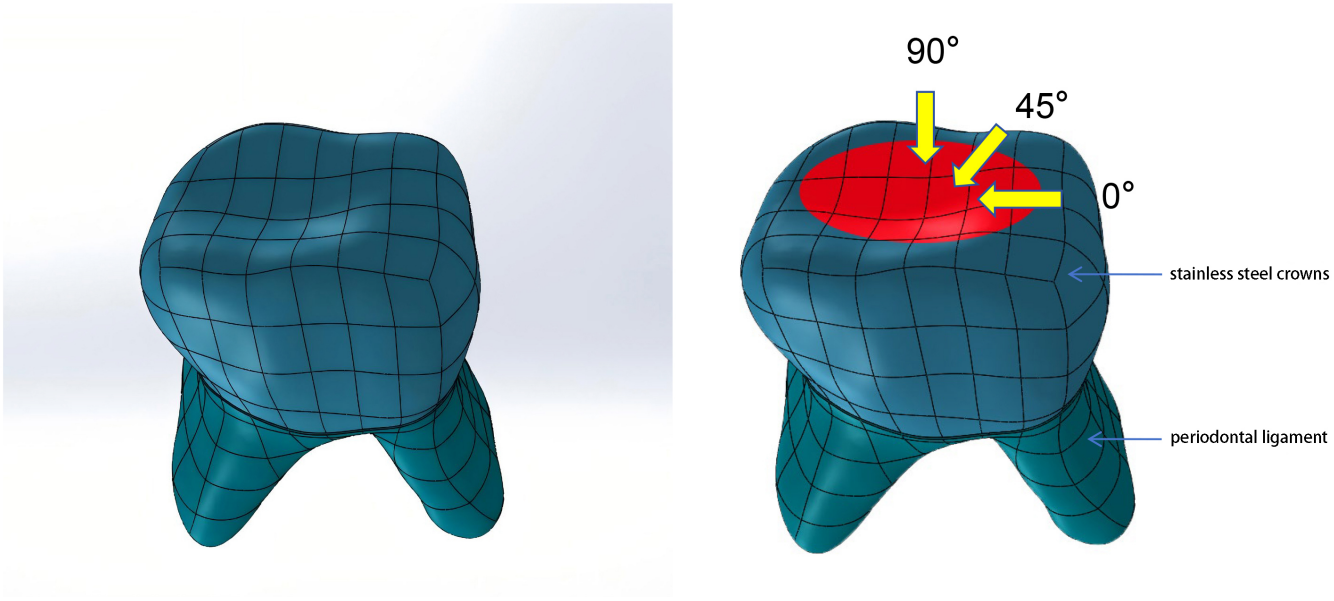

FIGURE 5. Simulation of the chewing force application surface and direction.

$+ \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \varepsilon$, where β_0 and ε are constant trend terms. $p < 0.05$, statistically significant.

3. Results

3.1 Stress distribution of teeth and periodontal ligaments before SSCs undergoing repair, and when occlusion returns to normal following SSCs repair

In Group A, Group B1, Group B2 and Group B3, the stress distribution of teeth is primarily concentrated at the apex and the cervical area of the tooth. The stress distribution of the PDL is primarily concentrated at the cervical area of the tooth and dispersed on the outer side of the root, as shown in Figs. 6,7 (In this article, all the finite element stress cloud charts are for a 3-year-old male child). The statistical description of the maximum Von-Mises stress in the PDL is provided in Table 2. Under normal occlusion conditions, the maximum Von-Mises stress in the PDL for Group A, Group B1, Group B2 and Group B3 is 6.146 ± 7.511, 8.539 ± 10.145, 8.047 ± 10.674 and 6.474 ± 7.462 MPa, respectively. Then, an ordered logistic regression model was used to analyze the differences in the maximum Von-Mises stress values of PDL between Group A and Groups B1, B2 and B3. The empirical results are detailed in Table 3. The regression equation for Group B1 is $Y = \beta_0 + 0.899X_1 - 0.019X_2 - 0.225X_3 - 0.239X_4 + 0.463X_5$, where β_1 is 0.899, indicating that after SSCs simultaneously repaired the first and second deciduous molars to normal occlusion, the maximum Von-Mises stress of PDL significantly increased compared to the group without SSC repair ($p < 0.01$). $\beta_2 = -0.019$, indicating that as the load angle increases, the maximum Von-Mises stress of PDL significantly decreases, with significant differences between the groups ($p < 0.01$). $\beta_4 = -0.239$ indicates that age is negatively correlated with the maximum Von Mises stress of PDL, with significant differences between the groups ($p < 0.01$).

The regression equations for Group B1 (Y_a) and Group B2 (Y_b) are as follows: $Y_a = \beta_0 + 0.812X_1 - 0.018X_2 - 0.211X_3 - 0.208X_4 + 0.614X_5$, and $Y_b = \beta_0 + 0.066X_1 - 0.018X_2 - 0.213X_3 - 0.212X_4 + 0.387X_5$. The coefficients β_1 are 0.812 and 0.066, respectively, with no significant difference between the groups ($p > 0.05$). The coefficient β_2 is −0.018, indicating a negative correlation between the maximum Von-Mises stress of PDL and the loading angle, with significant differences between the groups ($p < 0.01$). The coefficients β_4 are −0.208 and −0.212, respectively, suggesting that the maximum Von-Mises stress within the PDL decreases with

age, with significant differences between the groups ($p < 0.01$).

3.2 The stress distribution in the periodontal ligament (PDL) when occlusion height changes following SSC restoration of deciduous molars

In Groups B, C and D, the maximum Von-Mises stress in the crowns and PDL was concentrated in the cervical one-third region, gradually spreading laterally away from the root. The maximum Von-Mises stress in the maxillary right second deciduous molar was concentrated in the cervical and proximal one-third regions, with the remaining stress concentrated in the apical one-third region, as shown in Figs. 8,9,10. After SSC restoration, when the occlusal vertical dimension was increased from normal occlusion (0 mm) to 1 mm and 2 mm, the maximum Von-Mises stress in the PDL of Groups B2, C2 and D2 were 8.047 ± 10.674, 9.148 ± 12.308 and 12.983 ± 17.863, respectively. The maximum Von-Mises stress in the PDL of Groups B3, C3 and D3 were 6.474 ± 7.462, 7.355 ± 8.667 and 10.685 ± 12.872, respectively. The maximum Von Mises stress in the PDL of Groups B1, C1 and D1 were 8.539 ± 10.145, 10.593 ± 12.499 and 19.219 ± 23.337, respectively.

To further investigate the association between occlusal height, load angle, gender, age variables and the maximum Von-Mises stress in PDL after SSC restorations of deciduous molars individually and simultaneously, an ordered logistic regression model was applied to analyze the numerical data. The empirical results are presented in Table 4. The regression equation for SSC simultaneous restoration of the first and second primary molars is $Y = \beta_0 + 0.180X_1 - 0.020X_2 - 0.225X_3 - 0.174X_4 + 0.696X_5$, with $\beta_1 = 0.180$, indicating that as occlusal height increases, the maximum Von Mises stress in the PDL also increases ($p < 0.01$), with significant differences between groups. $\beta_2 = -0.020$ indicates that the maximum Von Mises stress in the PDL decreases with an increase in load angle ($p < 0.01$), with significant differences between groups. $\beta_4 = -0.174$ suggests that age is negatively correlated with the maximum Von Mises stress in the PDL ($p < 0.01$), with significant differences between groups.

The regression equations for SSCs to restore separately the first (Y_c) and second (Y_d) deciduous molars are as follows: $Y_a = \beta_0 + 0.144X_1 - 0.019X_2 - 0.205X_3 - 0.118X_4 + 0.304X_5$, and $Y_b = \beta_0 + 0.140X_1 - 0.018X_2 - 0.263X_3 - 0.132X_4 + 0.614X_5$. Where β_1 are 0.144 and 0.140, respectively. This indicates that as the occlusal height increases, the maximum Von-Mises stress in the PDL significantly increases ($p < 0.01$), with significant differences between groups. $\beta_2 = -0.019$ and -0.018, indicating a negative correlation between the loading angle and the maximum Von-Mises stress in the PDL ($p < 0.01$), with significant differences between groups. β_4 are -0.208 and -0.212, respectively, indicating that as age increases, the maximum Von-Mises stress in the PDL significantly decreases ($p < 0.05$), with significant differences between groups.

4. Discussion

Characteristics of early childhood caries include early onset, rapid progression and a tendency to involve the dental pulp. Additionally, due to young age, children often cannot cooperate for extended periods for complex comprehensive treatments without general anesthesia. Comprehensive oral treatments under general anesthesia offer the advantage of simultaneously addressing all carious lesions [24]. According to guidelines from the American Academy of Pediatric Dentistry, comprehensive treatment under general anesthesia is strongly recommended for early childhood caries, with SSCs advocated for restoring all decayed primary teeth [25]. Furthermore, a three-dimensional finite element analysis of primary molar teeth restored following root canal treatment with different restorations revealed that the stresses in the dentition of SSC restorations were more favourable than those of resin and inlay restorations [26]. Studies indicate that after SSC restoration of primary molars, occlusal overloading or interference beyond the tolerance of the PDL can promote root resorption of primary teeth, leading to tooth mobility, periodontal pockets or even tooth loss [10, 27]. In clinical practice, instances of premature loss of primary teeth have been observed following the primary molar restoration of their corresponding deciduous molars with SSCs. The precise mechanism of root resorption in primary molars remains unclear [28]. Nevertheless, it has been demonstrated that mechanical stress is a pivotal factor in the physiological root resorption of primary molasr [29]. In order to objectively verify the hypothesis that an increase in height following the restoration of deciduous molars by SSCs may promote root resorption in deciduous molars, it is unethical to verify this hypothesis by increasing the occlusal height of deciduous molars following the restoration of deciduous molars by SSCs in a clinical setting. However, 3D-FEA offers an excellent technical tool for evaluating the anatomical and histological structure of the study object and for analyzing any restorative material with mechanical properties and acceptable load stress cycling tests through computer numerical computational methods in the field of dentistry [30]. The research in oral biomechanics has resulted in notable time and cost savings. In this experiment, a 3D model containing teeth, periodontium, and alveolar bone was constructed from CBCT images with the objective of simulating the oral cavity. 3D-FEA was employed to investigate the impact of augmented occlusal height on the PDL subsequent to the restoration of primary molars with SSCs. This was undertaken to furnish a clinical foundation.

The findings of this study indicate that following the restoration of molar teeth by SSCs, the stresses within the SSCs were predominantly concentrated in the cervical margins and occlusal surfaces. In contrast, the stresses within the teeth were primarily concentrated in the apical region, while the stresses within the PDL were mainly distributed in the cervical portion of the teeth and dispersed in the outer portion of the roots. Furthermore, it was demonstrated that the PDL functions as a stress buffer layer between dentin and cortical bone, thereby facilitating the transfer of loading forces [31]. A comparison of the first or second deciduous molars restored by SSC with those not restored by SSC revealed no statistically

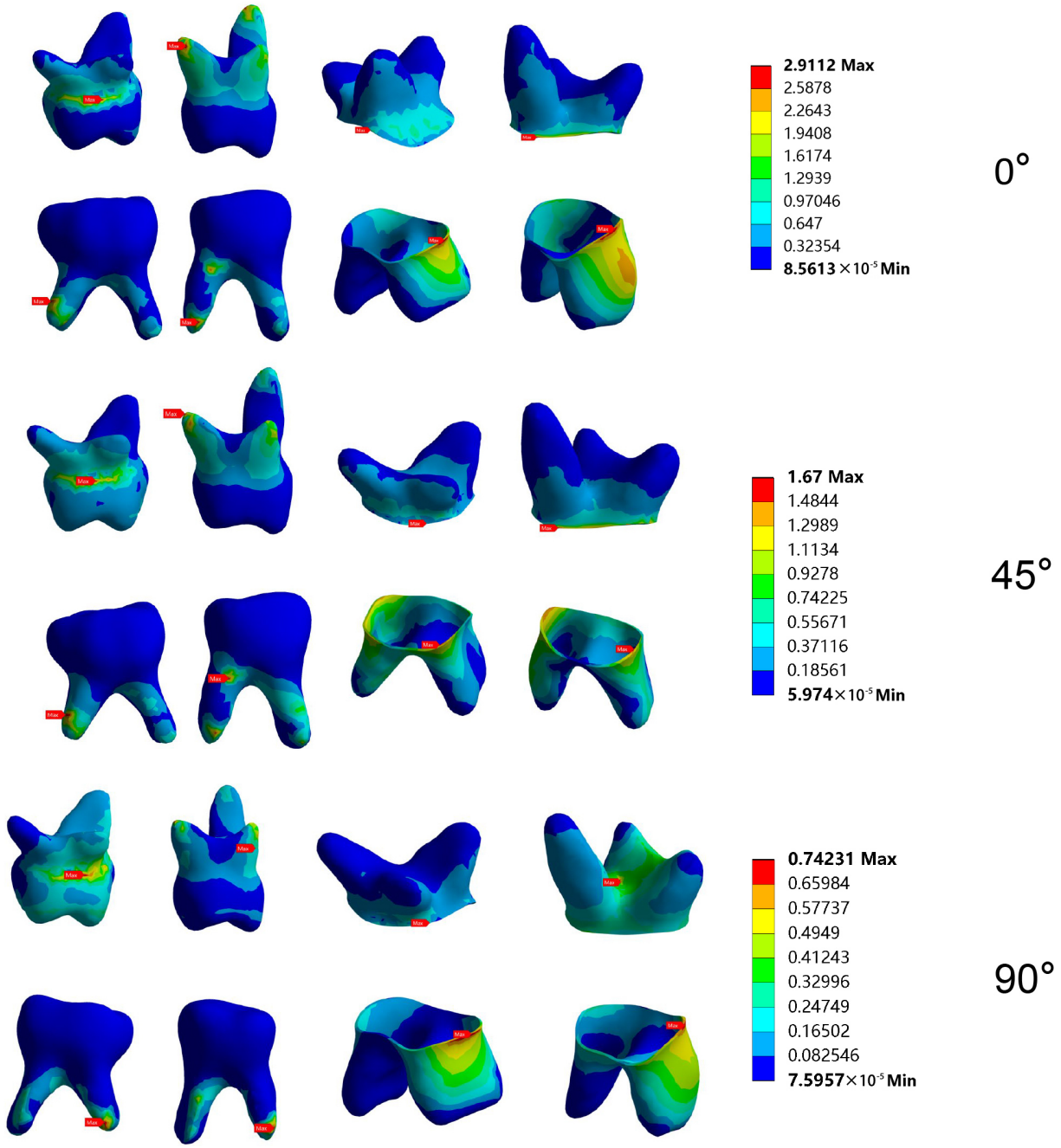

FIGURE 6. Stress cloud diagram of the group of SSCs unrepaired deciduous molars.

significant difference ($p > 0.5$) in the maximum von Mises stress values of the periodontal ligament (PDL). However, when SSCs were used to simultaneously restore the first and second deciduous molars to normal occlusion, a significant difference was observed in comparison with the group that underwent no SSC restoration ($p < 0.01$). In order to gain further insight into the impact of occlusal height adjustment on the PDL following the restoration of primary molas with SSCs, the maximum Von-Mises stress values of the PDL were subjected to analysis. The findings demonstrated that with an increase in occlusal height to 2 mm, the maximum Von-Mises stress values of the PDL exhibited a tendency to rise. This phenomenon occurred irrespective of whether the SSCs were restored on the first or second primary molar, or whether the SSCs were restored on both primary molars simultaneously. The observed difference between the groups was statistically significant ($p < 0.05$). This suggests that an increase in occlusal height may exert an influence on the periodontium. Additionally, previous literature has demonstrated that the occlusal height of deciduous molars restored with SSCs should be maintained within a range of 0.15 mm [32]. Although the actual forces acting on the PDL during mastication are dynamic and impact loads, the majority of current studies utilizing finite element simulation employ static concentrated loads, which are unable to accurately replicate the loads experienced by the PDL. Further research is required to enhance the reliability

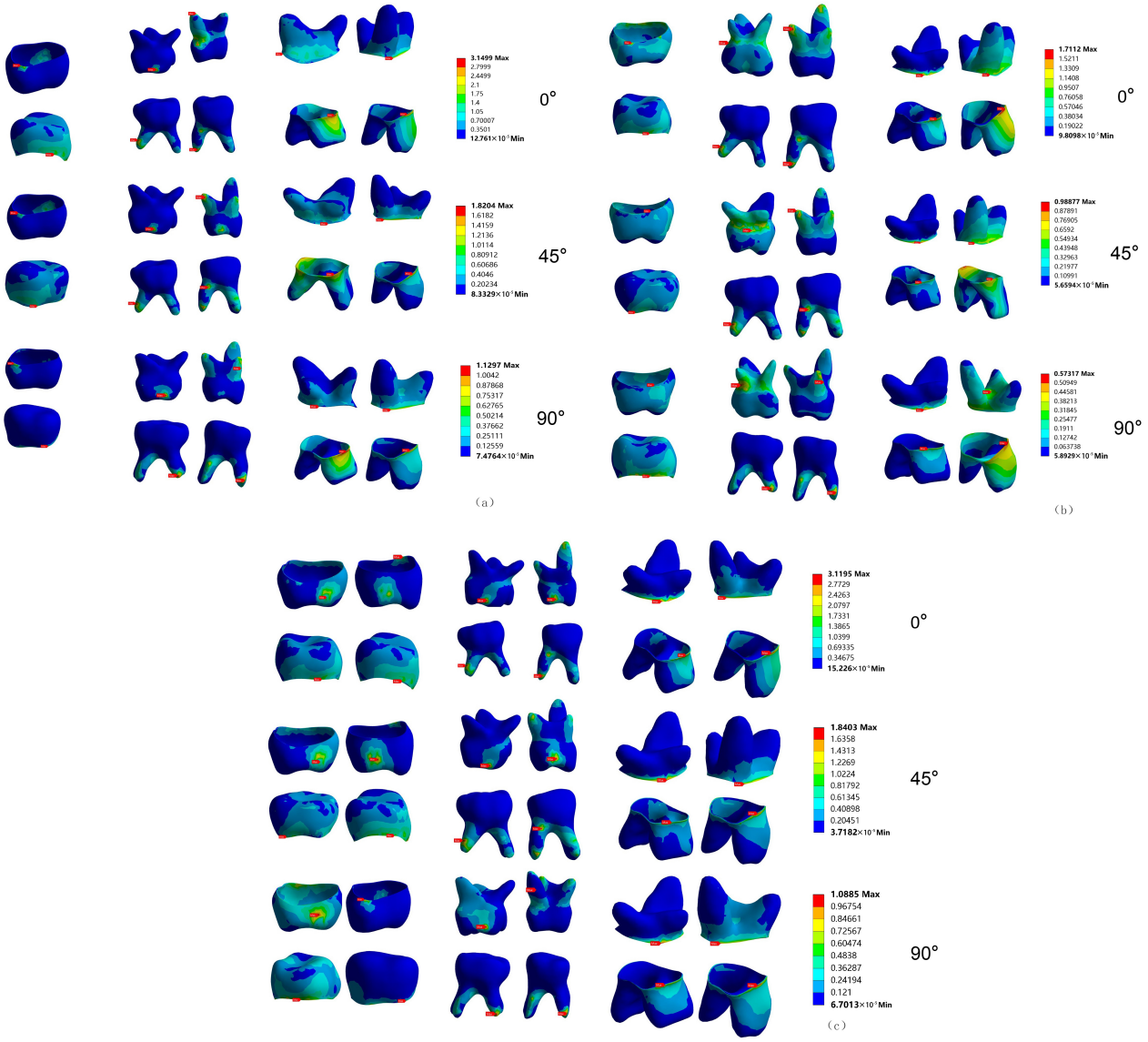

FIGURE 7. Stress Cloud Charts of SSCs repairing the first and second deciduous molars individually, as well as simultaneously. (a) Group B2, (b) Group B3, (c) Group B1.

of the experimental findings. Nevertheless, when exploring the biomechanical characteristics of PDL, experiments are more vulnerable to external factors and experimental parameters, whereas 3D-FEA can effectively compensate for this limitation. Moreover, 3D-FEA can be employed to validate the accuracy of the eigenstructural equation, underscoring the indispensable role of finite element simulation in the investigation of the mechanical properties of PDL [33].

Concurrently, an increase in loading angle is accompanied by a reduction in the maximum von Mises stress value of the PDL, with notable discrepancies between groups ($p < 0.05$). This finding is consistent with the notion that horizontal forces exert the greatest impact on periodontal health, while axial forces exert the least [34]. Furthermore, a negative correlation was observed between the maximum von Mises stress value of the PDL and age ($p < 0.05$). The maximum von Mises stress of the PDL was found to be greater in 3-year-old children than in 8-year-old children, indicating that the PDL of deciduous teeth with unresorbed roots is more sensitive to mechanical stimuli. This result is consistent with those of previous research [11]. Therefore, in clinical practice, after SSC restoration of deciduous molars, it is important to avoid early occlusal contact or significant occlusal interference, especially when both maxillary and mandibular deciduous molars are being restored simultaneously, as the PDL response to mechanical stimuli is more pronounced.

5. Conclusions

The Von-Mises stress values of the PDL were found to be at their maximum when the occlusal height was increased by 2 mm following the restoration of the molar teeth with SSCs with horizontally oriented loading (0°). It is therefore recommended that the occlusal height of deciduous molars after restoration by SSCs should be controlled within 2 mm in clinical practice. It must be acknowledged that this study is not without limitations, and as such, the results presented here should be verified by further clinical studies.

TABLE 2. Statistical description of the maximum Von-Mises stress in the PDL across different variables.

variables	Mean	Min	Max	SD
Groups				
A	6.146	0.037	22.171	7.511
B1	8.539	0.056	28.250	10.145
B2	8.047	0.052	31.047	10.674
B3	6.474	0.025	19.847	7.462
C1	10.593	0.067	34.105	12.499
C2	9.148	0.059	34.954	12.308
C3	7.355	0.027	23.383	8.667
D1	19.219	0.084	63.043	23.337
D2	12.983	0.076	51.832	17.863
D3	10.685	0.037	32.681	12.872
Angle				
0°	13.372	0.081	63.043	16.204
45°	11.400	0.066	55.661	13.983
90°	4.985	0.025	23.294	5.939
Tooth position				
#54	24.381	5.905	63.043	14.350
#55	14.846	4.680	37.547	8.638
#84	0.149	0.025	0.426	0.120
#85	0.300	0.107	0.924	0.173
Gender				
male	3.549	0.020	22.851	5.342
female	6.370	0.005	40.928	8.713
Age (yr)				
3	3.941	0.010	29.494	5.343
6	3.779	0.002	22.109	5.421
8	2.199	0.013	12.323	2.841

Note: #54 right maxillary first deciduous molar; #55 right maxillary second deciduous molar; #84 right mandibular first deciduous molar; #85 right mandibular second deciduous molars. SD: standard deviation; Min: minimum; Max: maximum.

TABLE 3. Analysis of the difference in the maximum Von-Mises stress in the periodontal ligament (PDL) before and after SSC restoration of deciduous molars.

Variables	B1	B2	B3
Bite height (0 mm)	0.899*** (−2.996)	0.182 (−1.245)	0.066 (−0.671)
Angle (0°, 45°, 90°)	−0.019*** (−4.492)	−0.018*** (−4.186)	−0.018*** (−4.233)
Tooth position	−0.225*** (−9.681)	−0.211*** (−9.511)	−0.213*** (−9.546)
Age	−0.239*** (−3.150)	−0.208*** (−2.792)	−0.212*** (−2.789)
Gender	0.463 (−1.555)	0.614** (−0.696)	0.387 (−1.307)
LLR	−613.64487	−622.67989	−621.54859

*Note: ***$p < 0.01$, **$p < 0.05$. LLR: logarithmic likelihood ratio.*

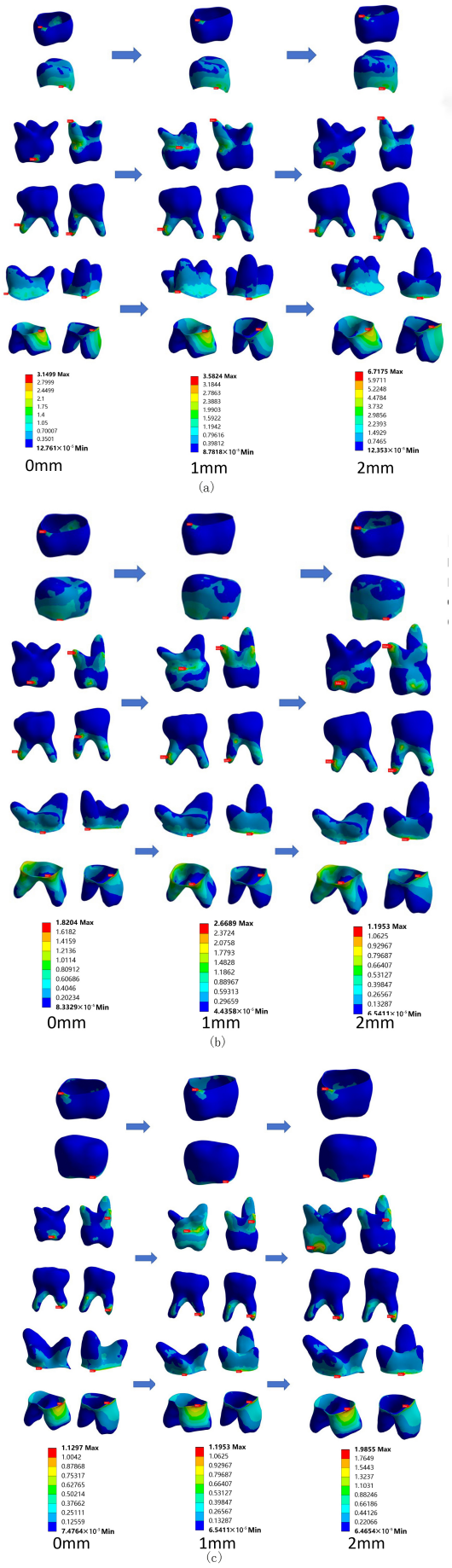

FIGURE 8. Stress nephogram illustrating changes in occlusal height and load angle after SSCs have repaired the first deciduous molars on the right maxilla and mandible. (a) 0°, (b) 45°, (c) 90° Load.

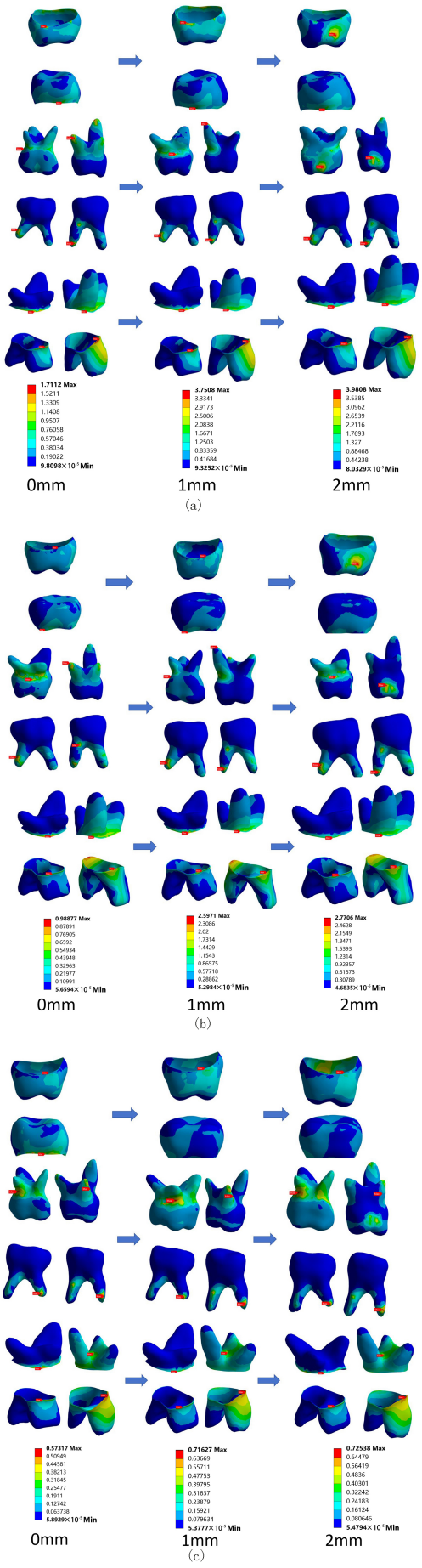

FIGURE 9. Stress nephogram illustrating changes in occlusal height and load angle after SSCs have repaired the second deciduous molars on the right maxilla and mandible. (a) 0°, (b) 45°, (c) 90° Load.

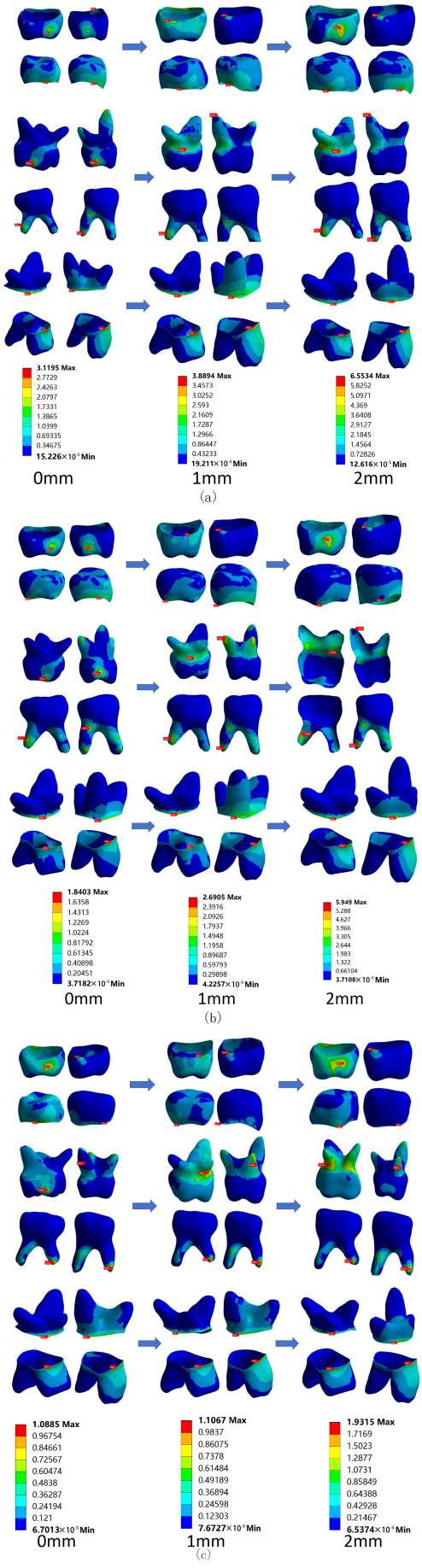

FIGURE 10. Stress nephogram illustrating changes in occlusal height and load angle after SSCs have repaired the first and second deciduous molars on the right maxilla and mandible. (a) 0°, (b) 45°, (c) 90° Load.

TABLE 4. Analysis of the variability in the maximum Von-Mises stress of the PDL across different variables following SSCs restoration in deciduous molars.

Variables	(1)	(2)	(3)
Bite height (0, 1, 2 mm)	0.144*** (−2.941)	0.140*** (−2.818)	0.180*** (−3.605)
Angle (0°, 45°, 90°)	−0.019*** (−5.607)	−0.018*** (−5.313)	−0.020*** (−5.679)
Tooth position	−0.205*** (−11.795)	−0.263*** (−10.170)	−0.225*** (−11.831)
Age	−0.118** (−1.971)	−0.132** (−2.176)	−0.174*** (−2.843)
Gender	0.304 (−1.262)	0.614** (−2.541)	0.696*** (−2.857)
LLR	−1021.8053	−1003.7219	−1008.2750

*Note: (1) SSCs was used to repair the right maxillary and mandibular first deciduous molars; (2) SSC was used to repair the right maxillary and mandibular second deciduous molars; (3) SSC was used for simultaneous repair of the right maxillary and mandibular deciduous molars. ***$p < 0.01$, **$p < 0.05$. LLR: logarithmic likelihood ratio.*

AVAILABILITY OF DATA AND MATERIALS

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

AUTHOR CONTRIBUTIONS

LNZ and JL—conceived the ideas; analysed the data; led the writing. LNZ, JL, JWG and KT—collected the data.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study has been reviewed and approved by the Medical Ethics Committee of Xinjiang Medical University (No: K202406-11). Informed consent was obtained from legal guardians of pediatric patients undergoing radio-graphic imaging.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jocpd.com/files/article/1875082438702448640/attachment/Supplementary%20material.docx.

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