Three-dimensional evaluation of facial morphology in children aged 5–6 years with a Class III malocclusion

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SUMMARY The aim of this study was to evaluate facial morphology in 25 Class III and 46 non-Class III children aged 5–6 years using three-dimensional (3D) laser imaging; 3D facial images were obtained, two average facial templates were constructed for the non-Class III male and female groups, each individual face was superimposed on the corresponding average template and group comparisons were evaluated (facial height, facial convexity, mandibular position and facial surface morphology). Differences between parameters were evaluated by using an analysis of variance and colour deviation maps. The results showed that Class III children had less mid-face prominence and a concave facial profile when compared to non-Class III children ($P = 0.002$ and $P = 0.018$). The position of the pg point in the z-axis just failed to reach statistical significance when comparing the two groups ($P = 0.051$). A vertical analysis showed no statistical significance between the groups, when evaluating middle (n–sn) and lower (sn–pg) facial height. Coincidence of the Class III faces to normal templates with a tolerance set as 0.5 mm was low (less than 30%). The soft tissue characteristics of a Class III face differ significantly from the non-Class III face in the mid-face region and in the facial profile. A 3D laser imaging method evaluated and identified morphological characteristics of Class III children in deciduous dentition, which could in the future become an important diagnostic tool in small children. The most important clinical advantage of this study is the non-invasiveness of the method.

Introduction

Class III malocclusion remains one of the most challenging malocclusions for treatment and early or late treatment remains a subject of debate (Campbell, 1983; Ngan, 2006; Ovsenik et al., 2007). Baccetti et al. (2005) suggest that the most appropriate time is during the pre-pubertal growth period derived from cervical vertebral maturation criteria. Furthermore, if the optimal time is not observed, it often results in permanent alteration in the path of closure, abnormal growth and subsequent facial deformity, and consequently treatment difficulty increases with age (Campbell, 1983; Guyer et al., 1986; Burns et al., 2010).

In order to start treatment with the appropriate appliance, early diagnosis of maxillary retrusion/mandibular protrusion in the deciduous or early mixed dentition is needed (Baccetti and Tollaro, 1998; Cozza et al., 2004; Ngan, 2006; Kilic et al., 2010). Most of the studies of early treatment of Class III malocclusion focus on hard tissue changes (Toffoli et al., 2008), although it is also important to estimate soft tissue facial characteristics as well since their changes play an important role in the evaluation and success of the treatment effects (McDonagh et al., 2001; Kilic et al., 2010).

Orthodontists have traditionally based their diagnosis and treatment planning on various records (e.g. photographs and radiographs) representing a three-dimensional (3D) subject in two dimensions. Studies involving irradiation of children are ethically questionable (Kau and Richmond, 2008). A laser scanner is a non-invasive device and has already been proved to be valid and reliable in patients with permanent dentition (Božič et al., 2010), mixed dentition (Kau et al., 2004) and deciduous dentition (Primožič et al., 2009, 2011).

Nevertheless, morphological characteristics of Class III malocclusion in the deciduous dentition have been poorly investigated (Chang et al., 1992; Tollaro et al., 1994, Choi et al., 2010). There have been no reports in the literature on 3D data of Class III children in deciduous dentition. The aim of this study was to evaluate and identify morphological characteristics of Class III children in deciduous dentition using a non-invasive 3D laser surface scanning method, for more effective, improved, non-invasive diagnosis and enhanced treatment planning.

Subjects and methods

Sample size estimation

Based on the recent studies (Primožič et al., 2009, 2011; Zhurov et al., 2010) and our previous experience in using the 3D system, it has been hypothesised that we could
expect a difference of at least 0.5 mm in the middle face area between Class III and non-Class III faces, with a standard deviation of 0.7 mm. With the standard values for the desired power (0.8) and type I error (0.05), this leads to required sample size of 62. Since Class III children are much more difficult to obtain than non-Class III children, two control group children for each Class III child were decided to be recruited, thus increasing the sample size to 72, with 24 Class III and 48 non-Class III children. Due to some recruiting problems, we eventually managed to get 25 Class III and 46 non-Class III boys and girls.

**Sample**

Two groups of children participated in this study. The first group consisted of 25 Class III children (9 males, 16 females; mean age 5.7 ± 0.6 years), selected from the files obtained from various paedodontic departments and dental polyclinics in Slovenia. The second group consisted of 46 non-Class III children (21 males, 25 females; mean age 5.6 ± 0.8 years) randomly selected from a kindergarten in the city of Kranj, with deciduous dentition, normal occlusion, no decays or extractions present and without functional irregularities. All Class III and non-Class III children went through a thorough clinical examination performed by a single experienced orthodontist (MO). Clinical examination of the face and facial appearance were besides the anterior crossbite and Class III molar relationship the diagnostic criterion for Class III malocclusion. All children were Caucasian in origin.

Ethical approval for this study was obtained from the Slovenian National Medical Ethics Committee at the Medical University in Ljubljana.

**Facial images**

3D facial images were obtained using two high-resolution Konica Minolta VIVID 910 laser scanners. Medium-range lenses (Konica Minolta) with a focal length of 14 mm were used. The cameras captured left and right sides of the face with a significant overlap in the front part of the face (Kau *et al*., 2005). The data were recorded on a laptop computer. The reliability and validity have been reported previously (Kau *et al*., 2004; Toma *et al*., 2009).

The 3D data were imported into Rapidform® 2006 (Inus Technology Inc., Seoul, Korea) and processed, using subroutines developed at Cardiff University (Zhurov *et al*., 2005), in order to remove unwanted data and then register and merge to produce a complete facial image. The resulting facial shells were further landmarked (Toma *et al*., 2009) by placing manually eight reproducible landmarks (nasion, outer and inner canthi, pronasale, subnasale, left and right cheilion and pogonion) and fitted into a common reference frame (Zhurov *et al*., 2010). The reference planes had their origin at mid-endocanthion, with the sagittal plane (yz) running through the midline of the face, the coronal plane (xy) established as an average natural head posture, and the transverse plane (xz) being horizontal and perpendicular to the sagittal and coronal planes. Mid-endocanthion has previously been shown (Zhurov *et al*., 2010) to be the most stable and reliable landmark of the front face.

Two average facial templates were constructed for the non-Class III male and female groups (Figure 1a) by using an improved version of the iterative template-averaging algorithm presented in Zhurov *et al*. (2010). The improvement involved scaling shells to the same relative size prior to averaging. The scaling factors were evaluated for each face based on the calculation of the centroidal parameter of the first principal component (Toma *et al*., 2011), which is essentially the distance between the straight lines through inner canthi and left and right cheilion.

Each individual Class III and non-Class III face was scaled to the size of the respective average face. The scaled faces were then superimposed on the corresponding average template using the iterative closest point method (implemented within Rapidform) and differences were quantified between respective facial areas restricted by the horizontal planes through inner canthi and subnasale (upper face), subnasale and commissures of the lips (mid-face), commissures of the lips and pogonion (lower face) (Figure 1b).

**Linear and angular facial parameters**

Nasion (n), subnasale (sn) and pogonion (pg) were chosen in order to evaluate the upper and lower face vertical dimensions, facial profile and position of the soft tissue pogonion point. The upper face vertical dimension was measured from n to sn and the lower one was measured from sn to pg. Furthermore, to assess facial profile, the angle between n, sn and pg was measured (Figure 1a) for all Class III and non-Class III faces. The position of pg was evaluated in the z-axis. The distances between Class III pg, non-Class III pg and the corresponding average facial template pg (pgAvg) were calculated. The directions of...
change (positive or negative) relative to pgAvg are indicated in Figure 2.

The 3D facial parameters

The shell-to-shell deviations of the superimposed faces were recorded: the average distances, standard deviations and percentages of concordance within 0.5 mm between facial shells. The colour histograms and colour deviation maps graphically illustrated the difference between facial shells. The regions that differed by no more than 0.5 mm were shown in black, blue colours highlight negative and red colours positive differences between the two shells.

Statistical analysis

The facial parameters for the Class III and non-Class III groups were statistically evaluated by using an analysis of variance (ANOVA). SPSS for Windows v18 (SPSS Inc, Chicago, Illinois, USA) was used. *P* values of less than 0.05 were considered statistically significant.

Results

The groups of 25 Class III children (9 males, 16 females; mean age 5.7 ± 0.6 years) and 46 non-Class III children (21 males, 25 females; mean age 5.6 ± 0.8 years) were balanced by age and gender (*P* > 0.05).

The means and standard deviations of the n–sn, sn–pg and pg–pgAvg distances as well as the n–sn–pg angle are presented in Table 1 and in Figures 3 and 4. With respect to the n–sn and sn–pg distances, no statistically significant differences were found (*P* > 0.05; *F*(1.71) = 0.52:*F*(1.71) = 1.27). However, female faces had significantly shorter n–sn distances (*P* = 0.039, *F*(1.71) = 4.43) and sn–pg distances (*P* = 0.021, *F*(1.71) = 5.63) than males.

With respect to the n–sn–pg angle, the ANOVA revealed a highly significant effect of Class III (*P* < 0.001, *F*(1.71) = 20.8). The n–sn–pg angle was larger in Class III (166°) than in non-Class III (160°) children. Furthermore, the gender difference was found to be statistically significant as well (*P* = 0.018, *F*(1.71) = 5.93); female faces had larger n–sn–pg angle than male faces.

With respect to the pg–pgAvg distance in the z-axis, the ANOVA revealed almost statistical significance in Class III (*P* = 0.051, *F*(1.71) = 3.95); the distances were larger in the Class III faces, indicating more protruded mandible. Regarding the gender difference, female faces had statistically significant larger distances than male faces (*P* = 0.024, *F*(1.71) = 5.36).

Morphological differences between the Class III shells and templates, evaluated by the median and the range of deviation from the corresponding average facial templates in restricted areas (upper face, mid-face and lower face) are shown (Figure 5). In the upper face and lower face, the ANOVA showed no significant differences between Class III and non-Class III groups (*P* > 0.05; *F*(1.71) = 0.01:*F*(1.71) = 2.51). The mid-face was more retrusive in Class III cases (*P* = 0.002, *F*(1.71) = 9.93). There were no statistically significant gender differences (*P* > 0.05).

The percentages of concordance for the facial shells (<0.5 mm) were 30% in upper face, 24% in mid-face and 25% in lower face. The Class III male and female faces superimposed on the average gender facial templates.
characteristics of Class III adults are already apparent reported that during the deciduous dentition the craniofacial demands a priority for early treatment (Campbell, 1983; Baccetti and Tollaro, 1998; Ngan, 2006). It has been according to several authors, a Class III malocclusion highlight a retrusive mid-face and a protrusive lower face (Figure 6).

Discussion

According to several authors, a Class III malocclusion demands a priority for early treatment (Campbell, 1983; Baccetti and Tollaro, 1998; Ngan, 2006). It has been reported that during the deciduous dentition the craniofacial characteristics of Class III adults are already apparent (Guyer et al., 1986; Chang et al., 1992; Tollaro et al., 1994; Choi et al., 2010).

Most of the studies diagnosing and planning treatment in Class III malocclusion in deciduous dentition are based on two-dimensional records (e.g. photographs and radiographs), representing a 3D subject in two dimensions (Chang et al., 1992; Tollaro et al., 1994; Choi et al., 2010). Furthermore, the studies involve irradiation risk that is ethically questionable to be used in studies on small growing children (Kau and Richmond, 2008). It is of great importance that the diagnostic tools are non-invasive, quick, precise and easy to use, especially in the studies on children in the years of growth and development (Kau and Richmond, 2008; Primožič et al., 2009, 2011; Djordjevic et al., 2011).

Figure 3 (a) Deviation of Class III and non-Class III n–sn distances (mm). (b) Deviation of Class III and non-Class III sn–pg distances (mm).

Figure 4 (a) Deviation of Class III and non-Class III n–sn–pg angles (°). (b) Deviation of Class III and non-Class III pg–pgAvg distances (mm).
The assessment of soft tissue profile is an important part in diagnosing and treatment planning and has been poorly investigated in Class III children in deciduous dentition. The soft tissue profile may reflect the underlying skeletal and hard tissues, and it may be possible to estimate the skeletal configuration by visual inspection of the soft tissue profile alone (McCance et al., 1997). Validation of surface anatomy of facial soft tissue is fundamental for an objective analysis of craniofacial morphologies in orthodontics. It is essential, when developing a treatment plan, to estimate facial changes along with occlusal improvements (Kilic et al., 2010).

The assessment of facial proportions in the vertical plane is an important part of diagnostics and treatment planning, especially in Class III patients, indicating the stability and success of treatment based on the growth pattern (Guyer et al., 1986). In the present study, a vertical analysis showed no statistically significant differences between the Class III and non-Class III groups, evaluating middle (n–sn) and lower (sn–pg) facial height, which coincides with the findings of Guyer et al. (1986), confirming that no increase in the lower face height is typically present in the deciduous dentition. However, in a skeletal analysis (lateral cephalogram), Chang et al. (1992) reported no difference in the upper face height and a significantly smaller lower face height in Class III deciduous dentition regarding the Chinese population.

In the quantification of the soft tissue profile, many different methods are used and the value of the measurement may be different depending on the method employed (Hwang et al., 2000). Although there are no absolute values that can be used to quantify ideal soft tissue relationships in the sagittal plane, it is generally accepted in adult population that soft tissue nasion, subnasale and pogonion are usually aligned vertically (McNamara et al., 1993). According to Ngan (2006), a straight or concave profile in a young patient indicates a skeletal Class III jaw relationship. For the profile assessment, the n–sn–pg angle was measured. In our study, a comparison between the Class III and non-Class III groups

![Figure 5](image1.png)

**Figure 5** Deviation of Class III faces from average facial templates in the upper face, mid-face and lower face (mm).

![Figure 6](image2.png)

**Figure 6** (a) A Class III male face superimposed on the average non-Class III male face; the mandible is protruded and the maxilla is retruded, with the shell-to-shell deviations within 0.5 mm shown in black (0.5 mm similarities between shells are 28% in lower face, 20% in mid-face and 41% in upper face), positive differences shown in red and negative differences shown in blue. (b) A Class III female face superimposed on an average non-Class III female face; the mandible is protruded and the maxilla is retruded, with the shell-to-shell deviations within 0.5 mm shown in black (0.5 mm similarities between shells are 21% in lower face, 50% in mid-face and 45% in upper face), positive differences shown in red and negative differences shown in blue.
indicated a highly significant difference in the convexity of the soft tissue profile, showing a difference of 6° in the n–sn–pg angle between the groups. Mandibular protrusion or maxillary retraction may be due to the increased concave profile in Class III. In previous studies, Chang et al. (1992) describe a concavity of the osseous profile and Choi et al. (2010) a concavity of the soft tissue profile in Class III deciduous dentition. The same results were found by Kilic et al. (2010) when analysing the soft tissue profile in the early mixed dentition.

Our findings showed that the Class III pg was positioned in front of the non-Class III pg and almost reached statistical significance, showing protrusion of the mandible. Previous studies, using lateral cephalograms, reported a more forward position of the mandible evaluating skeletal relationships in deciduous dentition, describing the SNPog angle (Chang et al., 1992), SNB angle (Tollaro et al., 1994; Choi et al., 2010) and pogonion to N-perpendicular (Choi et al., 2010) as being significantly greater in Class III. Similar results were also reported by Božič et al. (2010), using the same 3D laser scanning system in the Slovenian adult Class III population, which are in agreement with the results of this study.

According to the studies by Tollaro et al. (1994) and Choi et al. (2010), Class III children in deciduous dentition showed maxillary retraction and significantly larger mandibles compared to non-Class III children. Moreover, studies on the soft tissue evaluation revealed that the position of the upper lip was more retruded in the Class III group in deciduous dentition (Choi et al., 2010), while in the early mixed dentition, Kilic et al. (2010) found a retrusive maxilla and upper lip as well as protrusive mandible and lower lip. In accordance with these findings, the current study aimed to evaluate facial soft tissue morphological differences and showed a statistically significantly less prominent mid-face in the Class III group than in the non-Class III, indicating maxillary and upper lip retraction. Although the variables in the lower face, representing mandible and lower lip, did not reach statistical significance, our results indicate a tendency of mandibular protrusion.

Similarity of Class III patients to facial averages (differences less than 0.5 mm) was low (30% in upper face, 24% in mid-face and 25% in lower face). Likewise, Božič et al. (2010) showed also low concordance (33–38%) between the adult Class III face and the average facial template; however, the results involved the whole facial area.

As in previous studies, this study showed that only some typical soft tissue characteristics of an adult Class III patient are already present in a child in deciduous dentition. The results of this investigation may be explained by the patients age since the peak in the mandibular growth at puberty has not yet occurred (Baccetti et al., 2005; Alexander et al., 2009).

In the present study, Class III children in deciduous dentition showed more retrognathic facial appearance in the maxillary and upper lip area, compared to the average face of non-Class III children.

According to the results, forward orthopaedic traction of the maxilla, accompanied by corresponding forward movement of the soft tissue, should be considered in treatment planning of Class III malocclusion in deciduous dentition, which agrees with previous indications that point to pre-pubertal stages of craniofacial development as the optimal time for orthopedic intervention on the maxillary structures (Baccetti et al., 2005; Alexander et al., 2009).

A balanced soft tissue profile is a desired treatment objective in orthodontics. As it has been stated by Baccetti and Tollaro (1998) and Ngan (2006), the optimum timing for treatment of Class III malocclusion appears to be during the deciduous dentition, which is in agreement with our study.

With the development in technology, the evaluation of soft tissues in orthodontics with 3D imaging systems is slowly but persistently becoming an everyday practice. The 3D imaging enables the evaluation of an appropriate time that orthodontic treatment should be started. An orthodontic patient’s face with an evolving orthodontic anomaly can be scanned over a period of time in order to assess the direction of growth and the rate of change, which can be assessed and compared with either a previous scan or the average for that particular age (Moss, 2006). Where the soft tissue capture tools are available, treatment simulations allow the clinicians to better evaluate orthodontic anomalies, diagnose, analyse, plan and predict treatment outcomes (McCance et al., 1997) and accurately document the patient electronically in 3D.

Furthermore, we believe that it is important to create 3D norms for facial morphology in a given population that would eventually replace the traditional 2D cephalometric norms and lead to better diagnosis and treatment planning in orthodontic and dentofacial orthopaedics, in order to more effectively correct orofacial irregularities. This research will initiate further investigation of other malocclusions among different age groups in order to create databases, which will be applied clinically. In this study only faces built from our small database were included; for higher statistical significance, larger samples are needed.

We have shown that it is possible to use the 3D method in small growing children with Class III malocclusion. For the evaluation of the soft tissue profile, all previous studies of Class III children used the 2D methodology, which carries radiation risks and is therefore inappropriate for young children. We have for the first time in the literature described the soft tissue profile in Class III children in the deciduous dentition period using the non-invasive, quick, easy and reliable 3D methodology, which could in the future become an important diagnostic tool in the assessment of Class III malocclusion in small growing children. We wanted to emphasize that the most important clinical advantage of this study is the non-invasiveness of the method.
Conclusions
A non-invasive 3D laser surface scanning method evaluated and identified morphological characteristics of Class III children in deciduous dentition. The soft tissue characteristics of a Class III face significantly differ from the non-Class III face in the mid-face region and in the facial profile. Non-invasive 3D analysis proved to be an effective tool in the early diagnosis of Class III malocclusion in deciduous dentition. According to the results of this study, orthopaedic traction of the upper jaw arguably should be considered as the treatment protocol of Class III malocclusion in the deciduous dentition.

Funding
Slovenian Research Agency (ARRS).

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