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ORIGINAL ARTICLE

THE RESULTS OF GUIDED GROWTH VERSUS CORRECTIVE OSTEOTOMY IN TREATMENT OF CORONAL PLANE DEFORMITY AROUND THE KNEE IN SKELETALLY IMMATURE PATIENTS

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ABSTRACT

Background: The most prevalent orthopedic conditions in children are coronal deformities that affect the knee. The objectives of this study were to evaluate the clinical and radiological implications of knee-guided growth versus corrective osteotomy in the coronal plane deformity around the knee treatment, this study sought to compare their efficacy and safety.

Materials & Methods: This prospective comparative study that was performed on 60 cases aged > 4 years old, both sexes, with *Genu varum* and *genu valgum* with either femoral or tibial origin. Cases were divided into two equal groups: Group A underwent guided growth (GG), and Group B underwent osteotomy. Physical examination, laboratory investigation, radiological investigation, and history-taking were administered to all patients.

Results: Pain, total score, daily living activities, sport/play, and Group B exhibited a significant difference quality of life than Group A ($P<0.05$). During the 6-month postoperative period, radiological findings showed that Mechanical axis deviation (MAD) and Mechanical lateral distal femoral angle (mLDFA) of *genu varum* deformities in Group A compared to Group B were significantly improved ($P = 0.005$ and 0.038, respectively). In contrast, MAD and Mechanical medial proximal tibial angle (mMPTA) of *genu valgum* deformities ($P = 0.020$ and 0.043, respectively), as well as mMPTA of genu varum deformities and mLDFA of genu valgum deformities ($P=0.038$ and 0.037, respectively), in Group B compared to Group were significantly improved.

Conclusion: GG may be preferable in cases where gradual correction and lower morbidity are prioritized, whereas osteotomy may be indicated for more severe deformities requiring immediate correction.

KEY WORDS: Coronal; Deformity; Guided Growth; Knee; Osteotomy; Valgum; Varum.

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INTRODUCTION

In pediatric orthopedics coronal deformities around the knee are the most prevalent condition. A frequent observation in infants is the angular deformities around the knee prevalence, such as genu valgum and genu varum. Nevertheless, the preponderance of these deformities are physiological, caused by the typical physiological variations in the alignment of the mechanical axis from birth to adolescence.[1,2] The distinction between these physiological deformities and conditions, as rickets and skeletal dysplasia, is of the most importance, as most of the physiological deformities self-correct during youth and do not necessitate treatment.[3] Nevertheless, orthopedic management may be necessary for certain physiological deformities that may persist beyond adolescence. Consequently, it is crucial to select the appropriate patient. Conservative treatment is employed to address physiological deformities; however, surgical management is necessary for severe abnormalities that result in functional, cosmetic, and pain consequences. Historically, osteotomies have been the correcting deformities primary method in both adults and infants. The patient's morbidity is exacerbated by the following: delayed union, extensive soft-tissue dissection, malunion, wound closure complications,

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infection, and protracted immobilization. There are numerous categories of osteotomies. Each technique (reverse wedge, open wedge, closed wedge, and dome osteotomy) has its own set of advantages and disadvantages.[4] The intended correction is achieved by utilizing the plastic nature of physics in the context of guided growth (GG). It is a minimally invasive technique that has a lower morbidity than osteotomy.[5] GG is an appealing alternative that has become the preferred primary treatment for pediatric lower limb deformities. Historically, transient hemiepiphysiodesis has been performed following the completion of the knee's physiological remodeling. These techniques must be scheduled in accordance with the extent of the deformity and the residual available growth to prevent the permanent growth arrest risk.[6,7] Utilizing GG (hemiepiphysiodesis) as 8-plates, in skeletally underdeveloped patients, significant surgery, such as osteotomy and internal or external fixation, can be avoided by using treatments that are highly effective and have low complications for deformity correction. These plates have been extensively employed in all pediatric age categories and etiologies.[8] In order to evaluate the clinical and radiological implications of knee-guided growth versus corrective osteotomy in the coronal plane deformity around the knee treatment, this study sought to compare their efficacy and safety.

MATERIALS AND METHODS

This prospective comparative study was conducted on 60 patients older than 4 years, of both sexes, presenting with genu varum or genu valgum of femoral or tibial origin, including cases of Blount's disease, healed rickets, post-traumatic malunion, or Cozen's phenomenon. Patients were categorized into two equal groups of 30 cases each: Group A underwent guided growth (GG), while Group B underwent corrective osteotomy. Informed written consent was obtained from patients' relatives, and the study was approved by the Kafrelsheikh University Hospital Ethical Committee between 2023 and 2024. Patients younger than 4 years, those with physiological deformity, physeal closure, active metabolic disease such as rickets, or skeletal maturity were excluded. All patients underwent comprehensive clinical assessment including history taking, physical examination of rotational profile, joint range of motion (ROM) above and below the deformity, gait, limb length, foot deformity, and neurovascular status, laboratory investigations (complete blood count, albumin, calcium, iron, ferritin), and radiological evaluation with mechanical lateral distal femoral angle (mLDFA), mechanical medial proximal tibial angle (mMPTA), and mechanical axis deviation (MAD), assessed preoperatively and postoperatively at 0, 2, 4, 6 months and at 3, 6, and 12 months using plane AP and lateral standing X-rays. Corrective osteotomy was performed under general or spinal anesthesia depending on patient age and anesthetist preference, with tourniquet application to minimize bleeding. Pin orientation was adjusted to the post-correction osteotomy position with Schanz pins placed on either side of the planned osteotomy. Types of osteotomies included open wedge osteotomy preserving the contralateral cortex, closed wedge osteotomy utilizing CORA for pre-calculated wedge removal, and reverse wedge or dome osteotomy to correct coronal plane deformities in skeletally immature children while minimizing limb length discrepancy. Alignment was checked using a cautery lead cord from femoral head to mid-ankle ensuring mechanical axis alignment. For guided growth, patients underwent 8-plate insertion or transphyseal screws (PETS) under general anesthesia with tourniquet application, small skin incisions, fluoroscopic guidance, and proper fixation using titanium screws while avoiding joint cartilage injury.[9] Postoperative management included immobilization, physiotherapy, ROM exercises, gradual progression to full weight-bearing, and monitoring for complications such as superficial infection or overcorrection. Pain intensity was assessed at admission and after surgery using KOOS-Child to evaluate short- and long-term symptoms, physical functioning, and quality of life (QOL). Outcomes measured included length of hospital stay, wound healing, full ROM, and full weight-bearing. Statistical analysis was performed using SPSS v26 (IBM Inc., Armonk, NY, USA), with quantitative variables compared between groups using unpaired Student's t-test presented as mean ± standard deviation (SD), qualitative variables analyzed using Chi-square or Fisher's exact test expressed as frequency and percentage (%), and statistical significance defined as a two-tailed P value <0.05.

Intraoperative Imaging and Surgical Technique

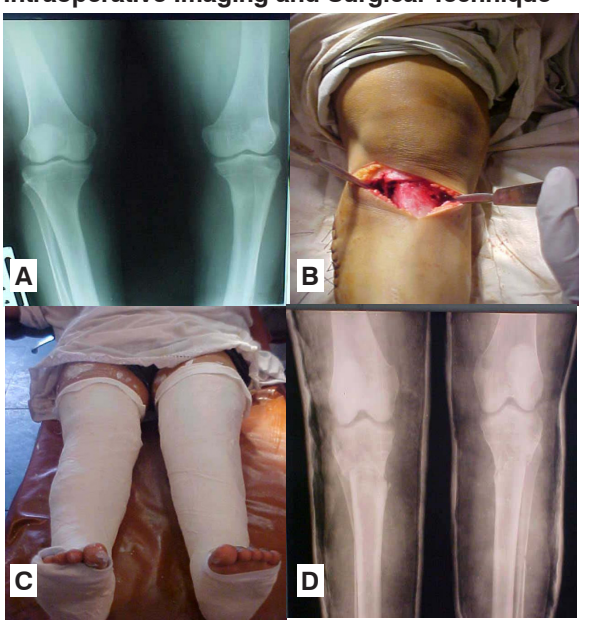

Fig 1: Radiological and Clinical Steps in Corrective Osteotomy for Bilateral Adolescent Tibia Vara

(A) *X-ray of 14 years old female with bilateral adolescent Tibin vara.*

(B) *Level of dome-shaped osteatomy just distal to the tibial tuberosity*

(C) *Immobilization of correction of osteotomy with above knee Cast.*

(D) *Immediate postoperative X-ray*

RESULTS

Total number of cases involved in our study was 60 patients and they were divided equally into two groups of 30 patients each. Group A consisted of 16 males and 14 females(10), while Group B included 18 males and 12 females. The mean age in Group A was 9.47 ± 3.54 years, compared to 10.33 ± 3.03 years in Group B .Table (1) shows that pain levels were significantly elevated in group B than in group A (P = 0.007). Group B exhibited significant improvement regarding the total KOOS score compared to Group A (P < 0.001), as ADL, Sport/Play, and QOL were also significantly improved in Group B. In contrast, age, gender, laterality and angular deformity, underlying disorders, and KOOS symptoms showed no significant differences between the studied cases.

Table 1: Demographic, deformity data, underlying disorders, and KOOS (immediately postoperative of the studied groups

Variable	Group A (n=30)	Group B (n=30)	P Value
Age (years)	9.47 ± 3.54	10.33 ±3.03	0.313
Gender			
Male	16 (53.33%)	18 (60%)	0.602
Female	14 (46.67%)	12 (40%)	
Laterality Deformity			
Right	14 (46.67%)	18 (60%)	0.301
Left	16 (53.33%)	12 (40%)	
Angular Deformity			
Genu varum	19 (63.33%)	17 (56.67%)	0.598
Genu valgum	11 (36.67%)	13 (43.33%)	
Underlying Disorders			
Blount's Disease	2 (6.67%)	1 (3.33%)	1.000
Cerebral Palsy	1 (3.33%)	0 (0%)	1.000
Achondroplasia	1 (3.33%)	3 (10%)	0.612
KOOS (Immediately Postoperative)			
Pain	3.6 ± 1.16	4.43 ± 1.17	0.007*
Symptoms	5.4 ± 1.25	5.77 ± 1.1	0.233
ADL	5.6 ± 1.04	6.87 ± 1.36	<0.001*
Sport/Play	3.07 ± 1.05	5.53 ± 1.17	<0.001*
QOL	4.9 ± 1.06	7.3 ± 1.25	<0.001*
Total Score	21.7 ± 1.8	27.5 ± 2.65	<0.001*

*Data presented as mean ± SD, or number (%). KOOS: Knee Injury and Osteoarthritis Outcome Score. Significant p-values are marked with an asterisk (**)**

Table (2) shows that during the 6 months postoperatively, radiological findings, MAD, and mLDFA of varus deformities were significantly improved in group A (P-value 0.005, 0.038, respectively).

Table 2: Radiological findings of Varus deformities

Time Point of Varus deformities		Group A (n=30)	Group B (n=30)	P value
MAD	Preoperative	20.58 ±4.74	19.12 ±4.62	0.357
	3 months	16.74 ±5.15	15.47 ±4.45	0.438
	6 months	11.79 ±5.14	7.29 ±3.64	0.005*
	12 months	7.74 ±4.85	6.71 ±3.74	0.484
mLDFA	Preoperative	99.95 ±8.71	98.12 ±8.59	0.531
	3 months	96.74 ±8.86	95.35 ±8.54	0.637
	6 months	95.42 ±8.84	89.41 ±7.7	0.038*
	12 months	90.21 ±8.82	88.94 ±7.64	0.649
mMPTA	Preoperative	79.58 ±3.64	80.59 ±3.12	0.381
	3 months	81.89 ±3.81	83.24 ±3.23	0.266
	6 months	86.11 ±3.94	89.53 ±3.36	0.009*
	12 months	90.32 ±4.14	90.06 ±3.4	0.841

MAD: Mechanical Axis Deviation

mLDFA: Mechanical Lateral Distal Femoral Angle

mMPTA: Mechanical Medial Proximal Tibial Angle

P ≤ 0.05 indicates statistical significance

Table (3) shows that Valgus Deformities: MAD and mMPTA in Group A (P = 0.020, 0.043, respectively), whereas mMPTA of varus deformities and mLDFA of valgus deformities showed significant improvement in Group B (P = 0.038, 0.037, respectively).

Table 3: Radiological Findings of Valgus Deformities

Time Point of varus deformities		Group A (n=30)	Group B (n=30)	P value
MAD	Preoperative	15.64 ±5.26	15.46 ±4.48	0.931
	3 months	11.27 ±5.2	11.46 ±4.67	0.926
	6 months	8.45 ±4.59	4.92 ±2.02	0.020*
	12 months	5.09 ±3.45	4.46 ±2.15	0.591
mLDFA	Preoperative	83.91 ±2.17	82.77 ±3.47	0.356
	3 months	87.09 ±2.63	86.23 ±3.09	0.475
	6 months	88.45 ±2.81	91.23 ±3.24	0.037*
	12 months	91.55 ±3.01	91.38 ±3.12	0.900
mMPTA	Preoperative	98.36 ±5.82	97 ±5.69	0.568
	3 months	95.36 ±5.87	94.31 ±5.57	0.656
	6 months	92.82 ±6.13	87.69 ±5.56	0.043*
	12 months	89.09 ±6.46	87 ±5.46	0.399

MAD: Mechanical Axis Deviation

mLDFA: Mechanical Lateral Distal Femoral Angle

mMPTA: Mechanical Medial Proximal Tibial Angle

P ≤ 0.05 indicates statistical significance

The 3-month preoperative, and 12-month postoperative radiological findings in Tables (2-3) (MAD, mLDFA, and mMPTA) there was insignificant difference between the study groups for both varus and valgus deformities.

Table (4) shows that the length of hospital stay was delayed significantly in Group B than in Group A (P <0.001). Full ROM and WB were in Group B significantly lower than Group A (P =0.005, <0.001, respectively). Insignificant differences were observed regarding wound healing, complications, superficial infection and overcorrection. In Group B, the time of bone healing ranged from 4 to 6 weeks.

Table 4: Outcomes and complications (immediately postoperative) of the studied groups

Parameters	Group A (n=30)	Group B (n=30)	P value
Outcomes			
Length of hospital stay (days)	1.43 ±0.5	2.5 ±0.51	<0.001*
Wound healing	29 (96.67%)	30 (100%)	1.000
Full ROM	28 (93.33%)	18 (60%)	0.005*
Full WB	29 (96.67%)	16 (53.33%)	<0.001*
Complications			
Superficial infection	3 (10%)	2 (6.67%)	1.000
Overcorrection	3 (10%)	1 (3.33%)	0.612

*(N=60) *: significant as P value ≤ 0.05*

DISCUSSION

The most prevalent type of coronal deformity in pediatric orthopedics is the one related to the knee. Conservative management is appropriate for physiological deformities; however, surgical management is necessary for severe irregularities that result in functional, cosmetic, and pain.[10] It is also possible to correct pediatric knee deformities acutely through the use of a variety of lower limb osteotomies. Hemiepiphysiodesis has been somewhat successful in either arresting or correcting deformities in children who are developing and have modest to moderate deformities.[1] Tibial osteotomy is typically necessary for individuals who are approaching skeletal maturity or have severe deformity. Acute correction can be achieved through tibial osteotomy with external or internal fixation, or at a gradual pace with external fixation.[11]

Age, sex, deformity type, and underlying disorder (Blount's Disease, Cerebral Palsy, and Achondroplasia disorders) exhibit statistically insignificant differences between the studied cases in the current study. Said et al.,[12] discovered that 30 skeletally underdeveloped patients, aged 13-14 years, with angular deformities. Of these patients, 15 underwent corrective osteotomy, and 15 underwent 8 plate hemi-epiphyseodesis. Results indicated that there statistically insignificant difference s regarding gender, laterality, angular deformity, and underlying disorders.

The patients mean age in group I was 6.7 ± 3.2 years (range, 3-14), while in group II it was 9.8 ± 3.7 years (range, 4-15). Nevertheless, there was a substantial disparity in age between the two groups. In comparison to patients in group II were significantly older, those in group I. The radiographic data revealed that

the preoperative, 3 months, and 12 months postoperative radiological findings (MAD, mLDFA, and mMPTA) of varus deformities and valgus deformities were not significantly different between the studied groups. However, during the 6 months postoperative period, they were significantly improved in group B compared to group A (P values 0.005, 0.038, and 0.009, respectively). Said et al.,[12] Emphasized that statistically insignificant difference was observed between the groups regarding preoperative radiographic parameters, such as HKA, mLDFA, and MPTA ($P>0.05$), varus and valgus deformities cases exhibited in radiographic parameters a statistically significant difference between the osteotomy and hemi-epiphyseodesis groups at the six-month follow-up ($P<0.05$). Specifically, the osteotomy group exhibited substantially superior angular measurements. There were no statistically significant findings at the 12-month follow-up. At the most recent follow-up, both groups of patients with varus and valgus deformities exhibited statistically significant improvement in all radiographic parameters ($P<0.05$).

Numerous prior investigations have documented the total improvement rates for mLDFA, mMPTA, and MAD without grouping in accordance with etiologies that employ two-hole tension band plating. The multinational study findings, which included 967 bone segments of 537 cases with varying causes who were managed with two-hole tension band plates, were reported by Danino et al. The mean correction rate for mLDFA was 0.77°/month, while the mMPTA mean correction rate was 0.79°/month.[13] For mLDFA, the mean correction rate was 0.65° (range, 0.05 to 1.67) months, while for mMPTA, it was 0.58° (range, 0.13 to 1.67) months. In addition, the authors reported that their MAD's overall correction was 1.73 mm/month (range, 0 to 6.4).[14]

One common practice is to perform full-length lower extremity weight-bearing radiographs every three to six months on individuals who receive GG for coronal plane deformities around the knee.[11,15] Nevertheless, certain patients' exhibit delayed correction rates, which may result in the exposure to higher radiation dosages as a result of the full-length lower extremity weight-bearing radiographs that are found every three for the peroi of six months. [16] The primary issue with the two-hole tension band plate hemiepiphysiodesis appears to be the deformity's rebound growth. Hsieh HC, et al., [11] reported a 3.8% rebound rate and Stevens [15] reported a 12.8% rebound rate; however, the quantitative measurement of rebound growth in these studies has not been precisely defined. Authors posited that the rebound phenomenon was a result of a change in mLDFA and mMPTA at 5° and above. In contrast to staples, which provide a rigid construct over their entire length, two-hole tension band plates offer a dynamic construct. Consequently, implant disintegration may still be observed during patients' follow-ups. [6] Braga SR, et al.[14], in their extensive series, they reported a screw fracture rate of 0.53% and asserted that all of the broken screws were metaphysical. The duration of hospital stay was substantially delayed in group B compared to group A in terms of outcomes. Group B exhibited substantially lower full ROM and WB than group A. The mean ± SD of 4.83 ± 0.83 weeks was observed in group B, where the time of bone recovery varied from 4 to 6 weeks. Nevertheless, there was no statistically significant difference in healing between the groups that were examined. The total score was significantly improved in group B in comparison to group A (P value <0.001), as ADL, sport/play, and QOL were significantly improved in group B compared to group A. However, the symptoms were not significantly different between the two groups. Pain was significantly higher in group B than group A (P value =0.007). Said et al., [12] group I had an average hospital stay of 1.5 ± 0.3 days (range, 1-1.9) and group II had an average hospital stay of 2.4 ± 0.3 days (range, 2.1-3). Compared to patients who underwent corrective osteotomy, epiphysiodesis necessitated a substantially shortened hospital stay (P=0.000).

In the postoperative period, all patients in group I were permitted to complete their full ROM and sustain their own weight. Nevertheless, group II was prohibited from practicing full weight bearing postoperatively. Full knee ROM was achieved in eight 53.3% patients in group II immediately following surgery. Postoperative protocol was statistically significantly different between the two groups $P<0.05$. A minimum of two days should be spent in the hospital for patients who undergo knee osteotomy. The patient must undergo months of physical rehabilitation and exercise, as the bone was intentionally fractured. Danino B, et al. [17], indicated that immobilization is not necessary, early weight-bearing is encouraged two days after surgery, and patients can return to school without restriction of movement two weeks after surgery. The examined groups did not exhibit any significant differences in terms of complications, including superficial infection and overcorrection. There were no reports of recurrence in the groups that were examined. Infection, wound hematoma, and wound dehiscence are complications that are not exclusive to TBP hemiepiphysiodesis in the early postoperative window. Additional complications include unintended physeal closure, over- or under correction, implant retraction, and failure of correction. As the primary site of failure, the 4.5-mm cannulated metaphyseal fastener has been identified. This screw will likely break at the point where the subjected screw penetrates the cortex, which is the result of three-point-bending if the metaphyseal portion of the plate is not directly opposed to bone. The epiphyseal fastener is also reported to be drawn through the physis and into metaphysis by others. This was ascribed by the authors to osteopenic epiphyses, the use of short fasteners, or the positioning of the screw too close to the physis. One patient who underwent anterior distal tibia TBP for recalcitrant equinus deformity was reported to have developed a physeal injury.[18,19]

As for complications, superficial infection and over-

correction were not substantially different between the groups that were examined. No recurrence was observed in the groups that were examined. Two cases in group II and one case in group I developed superficial infections, as revealed by Said et al. After antibiotic therapy and dressing, the infection was completely resolved. Overcorrection was observed in one patient in group II, while none of the patients in group I exhibited overcorrection. No one reported any neurovascular injuries, growth arrest, or deformity recurrence. Assan BR,[20] carried out a retrospective comparative investigation of GG in tibial osteotomy in children with Blount's disease. They discovered that the rate of correction and incidence of recurrence were both 78% in the hemi-epiphyseodesis group, with no rebound observed at a median follow-up of 10±2.4 months following the removal of the material. A recurrence rate of 60% was observed in the osteotomy group, with a correction rate of 10%. Maleki A, et al.,[21] discovered that incremental deformity correction is a more precise treatment for tibia vara than acute correction.

Özdemir et al.,[22] it the deformity recurrence was reported as the most prevalent complication was the in 70 bone segments 41.2%. A rebound deformity was presumed to be alteration in joint orientation angles of 5° or greater following the removal of the implant. Rebound deformity was observed in 40 (50.6%) femurs and 23(37.7%) tibias in the genu valgum deformity groups. The rebound deformity was observed in two (7%) femurs and five (19%) tibias in the genu varum deformity group. To rehabilitate four femurs and five tibias of the genu valgum groups' two-hole tension band plates were re-implanted. The determination of success in the treatment of coronal plane deformities around the knee has frequently been determined by the necessity of a corrective osteotomy. Tirta M, et al.,[15] noted that GG was employed to treat 63 of 65(97%) deformities, thereby avoiding the need for osteotomies. Some authors[15,19] have demonstrated the use of tension band plates resulted in 50 of 54 bone segments success 90%. They effectively applied two-hole tension band plate hemi-epiphysiodesis to 158 of 166 bone segments 95.2%. According to the existing literature, the findings of the present investigation were in agreement. We recommend providing larger sample size with multi-center cooperation to validate and generalize our results, provide follow-up period (1 year) to assess further possible complications or recurrence, and further research is required to well discuss and validate our results. The study had several limitations few of them were the relatively small sample size. The follow up of patients was limited for a relatively short period. The study was in a single center.

CONCLUSIONS

Guided growth and corrective osteotomy are effective interventions for the coronal plane deformities around the knee management in pediatric patients. Guided growth demonstrated superior short-term radiological correction of MAD and mLDFA in varus deformities, as well as MAD and mechanical mMPTA in valgus deformities. In contrast, corrective osteotomy resulted in greater improvements in mMPTA for varus deformities and mLDFA for valgus deformities. Additionally, patients who underwent GG reported significantly lower pain levels and superior functional outcomes, including better total scores, activities of daily living, sports/play, and QoL, compared to those who underwent osteotomy. These findings suggest that GG may be preferable in cases where gradual correction and lower morbidity are prioritized, whereas osteotomy may be indicated for more severe deformities requiring immediate correction. Further long-term investigations are warranted to evaluate the sustainability of these outcomes.

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CONFLICT OF INTEREST
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AUTHORS' CONTRIBUTION

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All the authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.